THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

ATHLETE ANATOMY

WHAT MAKES A WORLD CHAMPION BETTER THAN ALL THE REST?

AMAZING WEATHER

50 facts about the planet's diverse climatic phenomena

ROCKET LAUNCH PADS

The immense structures that propel spacecraft into orbit

7 ENGINEERING WONDERS OF THE WORLD

CRASH TEST CENTRES

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The magazine that feeds minds!

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FEED YOUR MIND!

If you stop to consider the inventive and often incredibly technical feats of engineering that have shaped both the physical and metaphorical landscape of our modern world throughout the ages, it's really quite mindblowing. For example, while once upon a time the humble bridge enabled our ancient ancestors to cross mildly impassable terrain, today's mega-bridges can span miles of water and canyons, stretch high into the sky and even extend far beneath the sea in some cases.

Of course, there's no denying the importance of the elementary design of a basic bridge, but with every new blueprint that emerges from an architect's drawing board comes a strong human desire to build it bigger, better and bolder. In this issue's big Technology feature we examine seven of the most exciting examples of such forward-looking engineering. Included in the lineup is a look at the seven-star luxury of a hotel built on its own island, an unthinkably massive behemoth of the mining world, and even the supreme precision engineering of the world's first commercially available quantum computing system. Feeling inspired? Let's never stop striving for bigger, better and bolder.

Enjoy the issue!

Helen

Helen Laidlaw
Editor

Meet the team...

Dave
Ed in Chief
The article on rocket launch pads makes for fascinating reading – it's all too easy to forget about all the technology and hard work that goes into a launch beyond the rocket itself.

Robert
Features Editor
Interviewing the brilliant ancient history expert Dr Michael Scott just hours before he attended the Olympic flame hand-over ceremony in Greece was a real highlight this issue.

Ben
Features Editor
You would have thought that, having been in a car crash myself, I'd want nothing to do with the 'Anatomy of a collision' piece on page 46. I suppose I just love to see things smash!

Adam
Senior Sub Editor
The range of history this issue is great, from the tank-like triceratops to the oracle at Delphi discussed in the interview, and on to medieval jousting. I defy anyone to find the past boring.

THE SECTIONS

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in Transport

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

SPACE
From exploration of our solar system to deep-space adventures

TECHNOLOGY
The wonders of modern gadgetry and engineering explained in depth

WITH THANKS TO...

How It Works would like to thank the following organisations for their help

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CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the experts in this month's edition of **How It Works…**

Shanna Freeman
50 amazing weather facts

This issue, writer Shanna has compiled a bumper crop of fascinating trivia about the weather. Whether you get a kick out of lightning, rainbows or weirder phenomena, there's something for all here.

Nigel Watson
Launch pads

Rockets often take the limelight during a launch, but Nigel wants to point out that these super-vehicles wouldn't be going anywhere if it weren't for the 'pad rats' and the impressive tech at the launch site.

Suzanne Worthington
Live TV broadcasting

Have you ever wondered how live filming differs from normal recording? What happens if something goes wrong? Well, we've enlisted Suzanne – an expert in digital media – to reveal how it all works.

Richard Aucock
Turbochargers

This issue, motoring specialist Richard is here to explain how turbos take the waste fumes of your car and convert them into additional power. Who said that you can't ever get something from nothing?

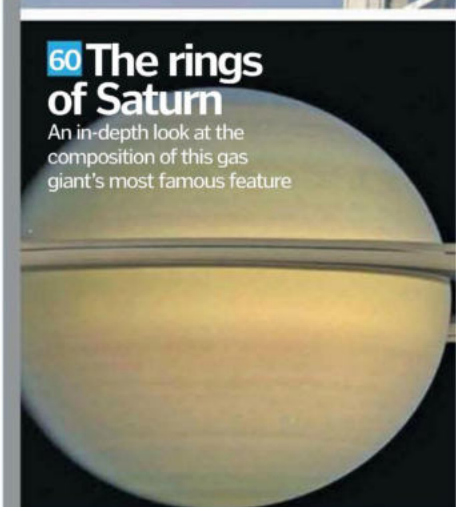
James Baker
Westland Lynx

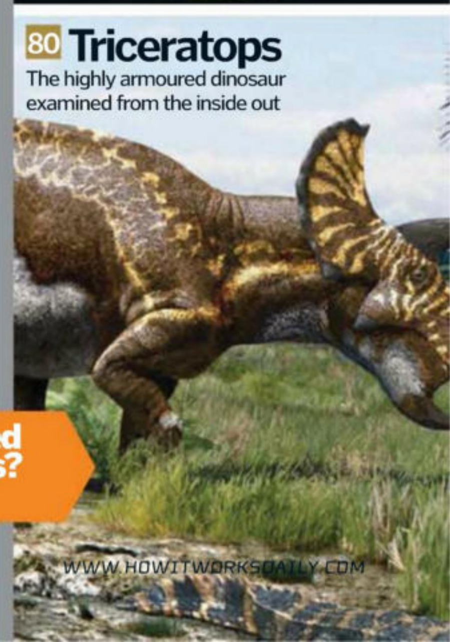
An authority on all things aviation, James breaks down one of the most impressive names in the helicopter field: the Westland Lynx. It broke the world speed record in 1986 and, amazingly, holds it to this day.

Susie Kearley
Detoxing

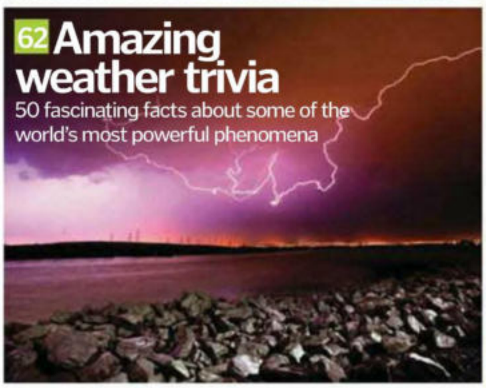
The liver is an incredible organ that takes out all the nasty toxins from the body and prepares them for excretion. Susie explains how this process plays out, step by step.

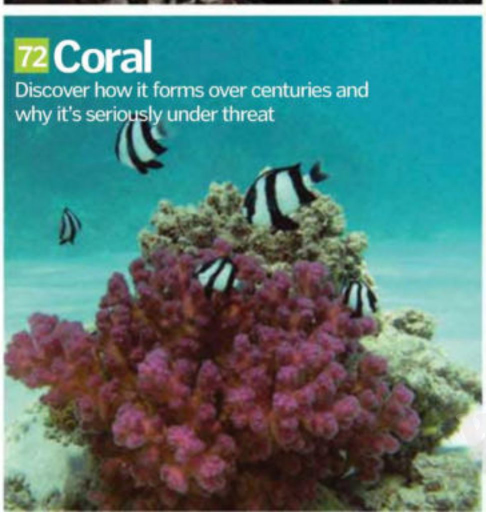
How are athletes tested for banned substances?
Go to page 36 to find out!





"Engineers today are the wizards, alchemists and even gods of yesteryear"





REGULARS

Revolutionary combat system revealed

Lockheed Martin recently demonstrated its brand-new Aegis Ballistic Missile Defense system for the very first time

US defence contractor Lockheed Martin has revealed the latest iteration of its technologically advanced Aegis Ballistic Missile Defense (BMD) system in a recent showcase.

The Aegis system, which has been designed to intercept hostile enemy missiles mid-flight, is currently installed on a series of US warships including the class-leading USS Arleigh Burke, from which numerous Raytheon RIM-161 Standard Missiles can be launched, as well as through interlinked ground-based sites. However, up until now, the Aegis system has been limited to handling only one interception at a time, leading Lockheed Martin to evolve its operation.

The new system, which was revealed on 16 May in a demonstration at the US Navy's land-based test facility in Moorestown, New Jersey, is now installed with a cutting-edge multi-mission signal processor (MMSP), a piece of kit that not only allows the evolved Aegis system to engage multiple threats simultaneously (both air and ballistic), but also nullify external aircraft and missiles' jamming systems.

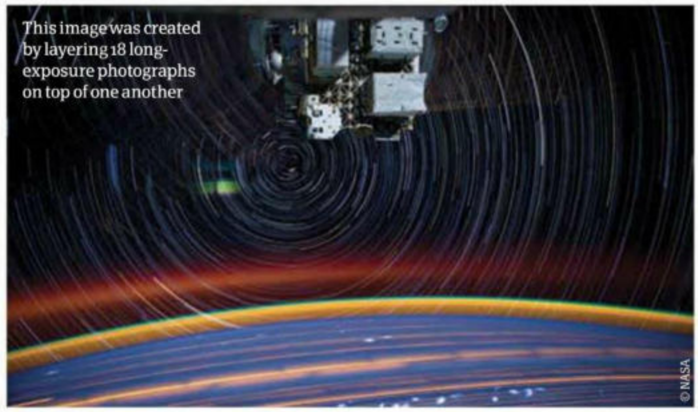
Speaking at the showcase, director of the Aegis programmes for Lockheed Martin, Jim Sheridan, said: "It's an exciting time to be part of Aegis's evolution. This test is the culmination of two years of hard work by our Lockheed Martin engineers and marks the start of a new era where the US Navy no longer has to choose between air or missile defence capabilities for any given mission."

Previous Aegis systems are currently installed on vessels in the US, Australian, Japanese, Norwegian, Spanish and South Korean fleets.

"The new system is now installed with a multi-mission signal processor"


A Standard Missile-3 is launched through the Aegis system on board USS Lake Erie


The host of missile launch bays on board USS Arleigh Burke


This image was created by layering 18 long-exposure photographs on top of one another

© NASA

Incredible star trail picture taken on ISS

A beautiful image that shows astral movements has been captured for the first time from the International Space Station

A unique image of some of our galaxy's star movements has been captured on board the International Space Station (ISS) by Expedition 31 flight engineer, Don Pettit. The image, which was photographed by a camera mounted externally to the station's body, was created through long-exposure photography, a process in which multiple long-exposure images are layered on top of one another. Speaking on the release of the image, Pettit said: "My star trail images are made by taking a time exposure of about 10-15 minutes. However, with modern digital cameras, 30 seconds is about the longest exposure possible, due to electronic detector noise effectively 'snowing out' the image. To achieve the longer exposures I do what many amateur astronomers do: I take multiple 30-second exposures, then 'stack' them using imaging software, thus producing the longer exposure."

Currently, the ISS is orbiting Earth at an approximate height of 385 kilometres (240 miles). During this transit, the camera was monitored by astronauts to ensure its continued operation and the final, psychedelic image (above) comprised a total of 18 shots.

GLOBAL EYE NEWS

WHAT ON EARTH IS IT?

A close-up look at the world!

Every month we post weird images on the HIW website for you to identify. Find out what they are now...

What is it?

1. Jump

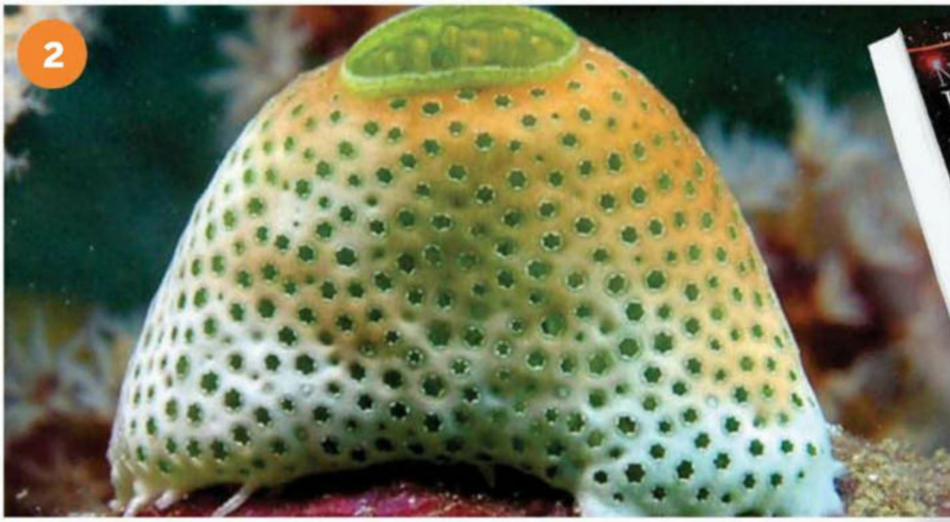
This is a closeup of a jumping spider, of which there are 500 genera within the family (salticidae) and approximately 5,000 described species. They differ from regular spiders in their ability to leap large distances to catch prey and their distinctive eye pattern, with each species having four pairs – a large set at the front and three smaller sets flanking each side of the head.

Your best answers:

A wolf or jumping spider? – **Barry Powderley**

A furry space alien? – **Rachael Stone**

What is it?



2. Robust

This is a species of sea squirt – atriolum robustum – perched on a soft tree coral. Robustum is a marine filter feeder with a sac-like morphology. To feed, organisms like this siphon and expel water through their bodies, absorbing plankton in the water. This species evolved in the early Cambrian period.

Your best answers:

A sea squirt? – **Arron Taylor**

A government experiment gone wrong? – **Matt O'Rourke**

What is it?

3. Peaked

This is an armet, or peaked helmet, a type of armoured headwear from the 15th century. The armet was the first piece of armour to completely seal the head in a light yet protective helmet. Most armets consisted of four pieces: the skull plate, two hinged and lockable cheek pieces, and a movable visor.

Your best answers:

An ancient perfume box? – **Ashwin Kumaar**

A pretty guillotine? – **Andrea Stefkova**

To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now!

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THIS DAY IN HISTORY

14 JUNE: How It Works issue 35 goes on sale, but what else

1287 Emperor Kublai Khan defeats the force of Nayan in East Mongolia and Manchuria.

1381 King Richard II of England meets leaders of the Peasants' Revolt at Blackheath, London.

1777 The Stars and Stripes design is accepted as the official flag of the United States.

1789 Survivors of the Mutiny on the Bounty reach Timor after crossing 7,400 kilometres (4,600 miles) in an open boat.

1822 Charles Babbage proposes his difference engine to the Royal Astronomical Society in London, UK.

Amazing new space magazine blasts off on 28 June

All About Space, the most exciting space magazine ever, will hit the shelves this summer

Imagine Publishing is proud to announce the launch of **All About Space**, which will be available in print and digital formats from 28 June. Packed full of cosmic content, **All About Space** will delve into the wonders of space exploration, astronomy and cosmic science every month, providing in-depth knowledge from a team of experts on a wide array of topics. The magazine is unlike anything else out there and will appeal to seasoned space fans and new explorers alike.

Inside you'll find fantastic illustrations and information on everything from Earth orbit to the edge of the universe. The first issue kicks off with a giant feature on the wonders of space, revealing the exciting missions that will be making headlines in the coming years. You'll also find articles on the new race to the moon, futuristic space planes, nebulas and much more. **All About Space** will make astronomy accessible to everyone with a host of stargazing articles explaining how to buy a telescope and what to look for in the night sky.

Dave Harfield, Editor-In-Chief, said: "**All About Space** is the most exciting magazine launch since **How It Works**. Space is a mindblowing topic and we're confident anyone fascinated by the cosmos will find **All About Space** the most amazing space magazine in this world or, indeed, any other."

All About Space will be available online at the Imagine eShop (**www.imagineshop.co.uk**) and in all good newsagents and supermarkets from 28 June. You can also download the digital version for iPhone, iPad and Android devices from **www.greatdigitalmags.com**. If you can't wait till then head to the **All About Space** website at **www.spaceanswers.com** to get your space fix now.

happened on this day in history?

© Carsten Ullrich

1900 Hawaii becomes a territory of the United States of America.

1940 Paris falls under German occupation during World War II.

1947 Wreckage of an alleged UFO is found at Roswell, New Mexico, USA.

1962 The European Space Research Organisation (ESRO) – which goes on to form the ESA – is founded.

© J Delanoy

1994 A riot occurs after the New York Rangers win the Stanley Cup from Vancouver.

Dr Michael Scott

With the Olympics nearly here, we talk to one of the world's foremost authorities on Ancient Greek culture about the way of life, the gods and Delphi's famous oracle

How It Works: What drives your fascination of this period of history, and Delphi specifically?

Dr Michael Scott: I'm currently writing a book about the entire history of Delphi and the reason I wanted to write it is that Delphi is so often solely about the oracle, when in fact there was so much else happening. There were the Pythian Games that were on a par with the Olympics, the monumental dedications in the sanctuary, the worship of many gods aside from Apollo, and a whole host of other roles.

The other reason though is that most coverage tends to focus on the classical and archaic periods (7th-4th centuries BCE). But this is a tiny town with a population of about 1,500 citizens running a tiny sanctuary and it manages, by hook or by crook, to [influence] a huge number of potentates from the 7th century BCE right the way through to the Roman emperors (including Nero and Hadrian in the 1st and 2nd centuries CE) and even on into the 4th century. Indeed, the site is not wholly abandoned until the Slavic invasions of Greece in the 7th century. I think it's a most extraordinary success story that deserves to be told in full.

HIW: What were the origins of the Sanctuary of Apollo at Delphi?

MS: The traditional story was that there was a settlement at Delphi stretching way back into the Mycenaean period - so we're talking from the 1400s BCE, but that settlement died out and then there's a [gap] between that and the [arrival] of the oracle at Delphi. One of the biggest advances in our understanding of the archaeology of the area in recent years has been to [effectively fill in] that gap.

We can now show this site is evolving as a place of habitation all the way from the earliest times of Greek history through many centuries. What we don't know - and what is almost impossible to get any sense of - is when exactly a religious sanctuary starts to be recognised here.

What we can say though is that, by the 8th century BCE, there is clearly some form of oracle building a reputation that spreads far from Delphi into the wider Greek world. By the end of the 7th century BCE this oracle, stuck up in the middle of nowhere in the Parnassian Mountains, is being consulted on some of the major questions that will affect the future for cities from all round the Mediterranean. And that is all happening, it would seem, before the sanctuary space itself has any kind of form or architectural elaboration.

So the sanctuary as it stands today looks nothing like it did in the 6th century BCE - when it was much less elaborate. And by then, the oracle has been going [strongly] for at least 100 years. We have to imagine that you've got this famous oracle that people are coming to from far and wide to ask big questions, [only to find] no grand sanctuary; we don't even know (at least according to the archaeological evidence) where the oracle was practising from at this time.

This puzzled even the Greeks. A lot of myths start to circulate at that time, like the god Apollo was pottering around the Greek landscape and eventually lands on Delphi as a nice spot to set up [camp] and then grabs passing Cretan sailors and drags them off course to make them the first priests of the Temple of Apollo. Oh, and in the meantime he has to slay a massive serpent that lives at Delphi called Python (which 'explains' why the site could be known as Pytho and Apollo was worshipped there under the particular name Apollo Pythios)!

The stories are fantastic and they were a fundamental part of Delphi, however they are creations of later generations of Greeks who were seeking to understand the world around them.

HIW: Ancient historian Herodotus speaks of the oracle at Delphi and others in his *Histories*, such as the tale of Croesus and Cyrus. How reliable a source is he?

MS: Herodotus is writing his big history - the first history - of the world at the end of the 5th century BCE. He was probably standing at Olympia during the Olympic Games making recitations of his work in the 420s BCE. The old style of looking at Herodotus and his oracle stories was to say, "Aha! Here is factual truth so we know that King Croesus sent emissaries to see the oracle all the way from Lydia in Asia Minor (modern-day Turkey) to ask this important question." Now people are more interested in two things.

Firstly, to look at the aims and goals of Herodotus as a writer. For example, it was clear that Herodotus was a big fan of oracle stories and there are tons of them in *Histories*. However, if we compare him to Thucydides, who takes up the Greek narrative directly after him, he does not like these stories. Thucydides is really not interested in oracles, [preferring] politics and fighting. So the Delphic oracle almost disappears from history then. It's the styles and interests of these writers that frame the history they write.

The second thing with Herodotus - and what is really interesting - is how he uses an oracle and an oracle story to [highlight] what people shouldn't be doing. Croesus is a perfect example of this. Croesus sends emissaries to various oracles around the Greek world and tests them. No Greek would do something so stupid as to test the oracles; these are the gods we're talking about, you don't test the gods! But King Croesus thinks you can find out which oracle is 'the best' so asks them to tell his emissaries what he is doing at a precise moment 100 days after they left. Of course, it is totally bizarre and, as the story goes, he was boiling a lamb and a tortoise together in a bronze cauldron and supposedly only Delphi got it right.

So now Croesus delivers his real question to Delphi, which is about war.

For more information about Dr Scott, you can go to **www.michaelcscott.com** or contact him via Twitter @drmichaelcscott

The frame of the question, according to Herodotus, is: "whether he should make an expedition against the Persians and whether he should make any further host of men his friends." And we know that, if we compare that question to other Delphic questions that are asked in Herodotus's *Histories*, that off the bat Croesus has asked his question in the wrong way. He has shown himself to be a barbarian because the question ought to be much more open.

So then you get the famed ambiguity of the oracle's response to Croesus, which goes along the lines of, "Croesus, having crossed the Halys [a river], will destroy a great empire." Of course, Croesus misinterprets the message and thinks it means his enemy's empire will fall, when in fact it turns out to be his own.

HIW: The Pythia was a key figure at Delphi in the prophesying process. Tell us about her role.

MS: We do not have a single ancient source that tells us explicitly from beginning to end how a consultation with the Pythian priestess went. It is either something that was so well known that everyone knew about it and didn't bother writing it down, or so secretive that you weren't allowed to write it down.

> **"One popular belief was that there were some vapours that emerged from a cavern beneath the temple that 'inspired' the priestess"**

We know about certain stages; for example, if you were a consultant you turned up, paid some money, waited in a queue (though certain people could skip this) and then entered the temple. However, it is from here that our knowledge becomes uncertain.

In fact, for such important individuals, who held sway and changed the tides of Greek history so often, we only know the names of but a couple of Pythian priestesses. We know they were usually women from the city of Delphi and that although originally young women took the role, in later times women over 50 were more common. We also know that at one point the oracle was so popular they had two Pythian priestesses on the go and a third in reserve, and we also know a little about their daily routine. However, we do not know how they were 'inspired' [or enlightened] by Apollo.

One popular belief was that there were some vapours that emerged from a cavern beneath the temple that 'inspired' the priestess. However when they went to excavate the sanctuary at the end of the 19th century, no such caverns were found. People have now done lots of anthropological work showing that if someone is indoctrinated into a set of beliefs strongly enough it can almost be a self-hypnotic mechanism.

HIW: How important were the oracles of Ancient Greece to its culture in general?

MS: Fundamental. You have to picture yourself in a world where the gods are in control of everything. There is no way that any plan of yours is going to succeed unless the gods want it to. And in that kind of mindset, atheism is not really an option. It's very hard to think outside the box. As such, it makes absolute sense to find out what the gods are planning and what they are happy to [endorse]. In that sense consulting an oracle is a completely rational occurrence. But what we have to factor in is that Delphi was just one place and just one way to consult the deities.

There were many other methods. You could watch the way water rippled, or the way leaves shook in the breeze. You could get an oracle-peddler, a guy on the street, to tell you the will of the gods by reading his 'oracle books'. You could sacrifice animals, looking at the patterns on their organs. You could even go and consult the dead at various sites.

What kind of oracular engagement you go for depends on different things [time and money being two major factors]. For example, to go from Athens to Delphi took several days and even then you could only go on one of nine days in the year (the only days the Pythian priestess was available). Once you were there you had to spend a good deal of money. In other words, it was a huge investment.

Taking this into account, it's not surprising that at no point during Ancient Greek history do we find people rejecting in any real way oracular consultation as a useful and effective way of going about your business. And, more importantly, we don't have a single example of any big state question where the Delphic oracular response is ignored or contravened. The oracle can be misunderstood, even a different answer demanded, but it always holds sway for over a thousand years.

Dr Scott is research associate and affiliated lecturer at the Faculty of Classics and Darwin College, University of Cambridge, UK. He is working on two upcoming books: *Space And Society In The Greek And Roman Worlds* and *Delphi: Centre Of The Ancient World*, due to be published in November 2012 and in 2013, respectively.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

© NASA

1 Alien super-Earths exist

NASA has uncovered a 'super-Earth' orbiting a star called 55 Cancri in a system 41 light years away from Earth. The Spitzer telescope detected infrared light directly from 55 Cancri e, a planet twice as big as our own, and with eight times the mass. It's a world of rock surrounded by water and steam in a supercritical state, with the sun-facing side a molten 2,000 Kelvin (1,727 degrees Celsius/3,140 degrees Fahrenheit).

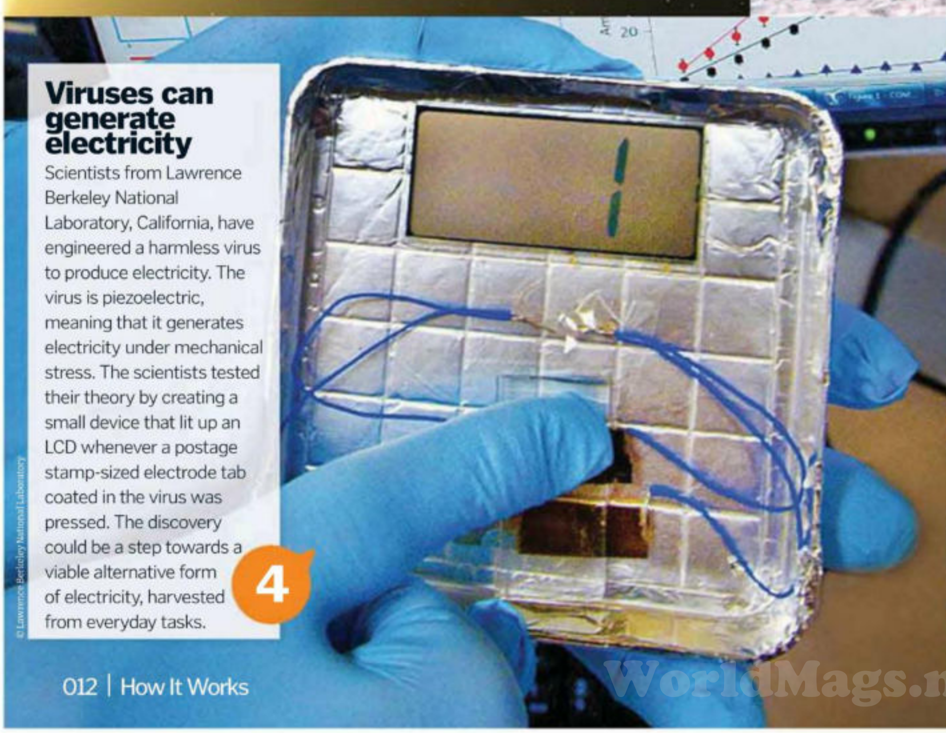
> "55 Cancri e is a world of rock surrounded by water and steam in a supercritical state"

2 Maggots are the Sherlock Holmes of the animal kingdom

Police are increasingly turning to entomologists to help solve murders. Insects and their larvae found on a body can give a clear indication as to how long the body has been there. They can also indicate whether the body has been moved and the cause of death. Human DNA, drugs and other important clues can even be found in flies that have fed on a corpse.

3 Sharks aren't attracted to magnets

Research by an American chemist has shown that certain elements with magnetic properties can repel sharks. Samarium, neodymium and praseodymium react in water to produce an electric current, which some sharks will swim away from the moment that they're within range. The theory is that a shark's ampullae of Lorenzini organs – found on the snout – with which they use to locate prey and navigate are overloaded by the electric field.



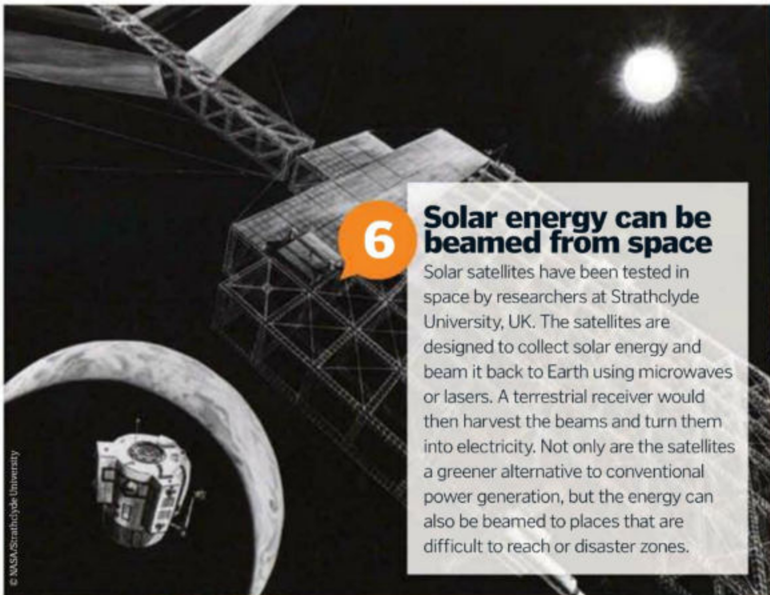
© Lawrence Berkeley National Laboratory

4 Viruses can generate electricity

Scientists from Lawrence Berkeley National Laboratory, California, have engineered a harmless virus to produce electricity. The virus is piezoelectric, meaning that it generates electricity under mechanical stress. The scientists tested their theory by creating a small device that lit up an LCD whenever a postage stamp-sized electrode tab coated in the virus was pressed. The discovery could be a step towards a viable alternative form of electricity, harvested from everyday tasks.

5 Terahertz Wi-Fi is coming

Japanese researchers have broken the wireless data transmission record by transmitting in the terahertz band. The 'T-Ray' area of the spectrum is anything from 300GHz to three terahertz, 60-600 times higher than the fastest Wi-Fi standard currently available. The range is limited; terahertz Wi-Fi would only work over around ten metres (33 feet), but a first generation of T-Ray Wi-Fi could be up to 15 times higher than the next-generation standard, 802.11ac.



© NASA/Strathclyde University

6 Solar energy can be beamed from space

Solar satellites have been tested in space by researchers at Strathclyde University, UK. The satellites are designed to collect solar energy and beam it back to Earth using microwaves or lasers. A terrestrial receiver would then harvest the beams and turn them into electricity. Not only are the satellites a greener alternative to conventional power generation, but the energy can also be beamed to places that are difficult to reach or disaster zones.

7 Britain's getting more tropical

The tropics – the band around the equator delineated by the Tropic of Cancer in the north and the Tropic of Capricorn in the south – are getting bigger. Ozone depletion in the atmosphere is being blamed for a widening of 0.7 degrees per decade over the last 30 years. In the short term, if this progression towards the poles continues, sub-tropical areas will become gradually drier while more temperate areas – such as that the UK occupies – will become hotter and wetter.

© NASA

8 Planes are having a makeover

NextGen is the name of a new wave of air transport vehicles being researched by NASA and several other US government agencies. The idea is to change the fundamental design of transport aeroplanes, with boxed wings and a different engine placement in order to reduce drag and increase fuel efficiency.

9 Dogs made us human

We know that dogs have been an integral part of human society for thousands of years, but anthropologist Pat Shipman is now suggesting that our canine companions played a key role in ensuring our ancestors came out ahead of our primate cousins. Over 32,000 years ago, homo sapiens ousted neanderthal man from Europe using domesticated wolves as essential 'tools' to ensure success for both hunting and defending ourselves.

© NASA

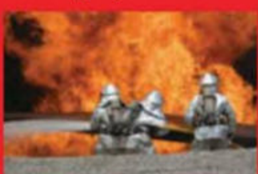
10 Armageddon movie is to become a reality

NASA is training a team of astronauts to land on an asteroid. Major Tim Peake and five others will spend 12 days in a cramped underwater base to simulate the conditions they will experience exploring a large near-Earth asteroid. The idea is that a team will be on-hand with the skills to deal with a potential planet-killer, should a big enough asteroid on a collision course be spotted too late to send a robotic deflection mission.

Welcome to... **TECHNOLOGY**

Long ago, seven structures captured humanity's imagination. Putting a modern twist on the concept we've compiled a septuplet of fresh engineering feats, each of which has, in its own way, changed the world.

24 Olympic Stadium



26 Fire suits

28 Live TV tech

LEARN MORE

7 ENGINEERING WONDERS OF THE WORLD

Humankind's engineering ingenuity is pushing out a new wave of mechanical, electrical and structural wonders, superseding their predecessors in every way, delivering mind-bending levels of power, speed and strength

How far can we manipulate matter? Bend the conventional rules of physics? To what extent can we push the engineering envelope to create mechanical wonders that not only broaden humanity's horizons but also reaffirm the ability of science and technology to improve people's lives? The answer, it seems, is further than anyone ever thought possible.

Engineers today are the wizards, alchemists and even gods of yesteryear, achieving miracles that once would have been deemed impossible. Thanks to their judicious study of mathematics, geometry, algebra and material sciences, today's top engineers can defy gravity, travel across the Earth in mere hours and create computational systems to explore reality at a quantum scale. And all this is just for starters...

Like the heroic fables of old, these achievements should be celebrated and, as such, How It Works has put together a list of seven of the modern world's most spectacular engineering accomplishments. From hypercars and seven-star hotels, through to monstrous 45,000-ton earth excavators and on to hypersonic jets capable of travelling at around 21,000 kilometres (13,000 miles) per hour, what follows are some of the mechanical marvels currently pushing the boundaries.

Original
1 The original list of the world's seven wonders stems from the 1st century BCE, where Hellenic tourists would visit numerous sites around the Mediterranean.

The survivor
2 Of the seven wonders of the ancient world, only one remains on today's list: the Great Pyramid of Giza. The others are now either ruins or completely destroyed.

Helios
3 Of the ancient wonders, one of the most impressive was the Colossus of Rhodes, a 33-metre (107-foot)-tall statue of the Greek Titan Helios. It was destroyed in an earthquake in 226 BCE.

Lighthouse
4 Another of the most notable ancient wonders was the Lighthouse of Alexandria, which at the time was the largest structure on Earth. An Egyptian proposal to rebuild it was tabled in 2008.

Myth
5 One of the ancient wonders is considered by many to be a myth. The Hanging Gardens of Babylon were said to have been built in the 6th century BCE, however no first-hand evidence exists.

DID YOU KNOW? The Agera R can accelerate from 0-200mph in a mere 17.68 seconds

The advanced hypercar

Like a brutal blow to the face by Thor's warhammer, Koenigsegg's Agera R demolishes traditional ideas of speed and power in a fury of burnt hydrocarbons

Can you race a lightning bolt? Well, considering that would mean travelling at close to 225,000 kilometres (140,000 miles) per hour, probably not. Nevertheless, Swedish hypercar manufacture Koenigsegg is giving it its best shot with its latest model – the Agera R – which is capable of obliterating the 440-kilometre (273-mile)-per-hour mark without even breaking a sweat.

We're talking about a vehicle with a colossal 850 kilowatts (1,140 horsepower), earth-moving torque of over 1,200 Newton metres (885 foot pounds) at 4,100rpm, an intense 1.4 bar turbo boost pressure, a lateral g-force of 1.6 g, a pure aluminium five-litre (1.3-gallon) V8 engine and a carbon-fibre intake manifold with optimised intake tract. Not only this, but this hypercar delivers all of these things at a stupidly low (dry) weight of just 1,330 kilograms (2,932 pounds) and, as such, can accelerate from 0-60 miles per hour in an eye-watering 2.9 seconds.

Talking of statistics, the Agera R isn't a mere flash-in-the-pan in terms of speed, topping out after an initial burst of energy. Shift up through its seven-speed, dual-clutch transmission and then employ ventilated ceramic disc brakes with six-piston callipers, and you'll find yourself moving from 0-200 miles per hour and then back to 0 in just 21.2 seconds. How is this possible? To name but one of many reasons, it's down to the fastest and most efficient traction control system in the motoring sphere.

Highly qualified engineers have delivered the lightest, most compact hypercar engine in the world, complete with a clutch, flywheel, dry sump and Inconel manifold system with turbos, all in a package that weighs less than 200 kilograms (441 pounds). It also boasts a revolutionary new response/back-pressure reduction system to grant the Agera R instantaneous turbo response. Further, these engineers have designed waterless, air-to-air intercoolers for the vehicle, both reducing weight and improving acceleration speed significantly.

> "The Agera R is capable of obliterating 440 kilometres (273 miles) per hour without even breaking a sweat"


A semi-stressed engine and gearbox with support struts deliver optimal rigidity

The statistics...

Agera R

Length: 4,293mm (169in)
Width: 1,996mm (78.6in)
Height: 1,120mm (44.1 in)
Dry weight: 1,330kg (2,932lb)
Engine: 5l (1.3ga) V8
Power: 850kW (1,140hp)
Max speed: 440km/h (273mph)
Max torque: 1,200Nm (885ft lb) at 4,100rpm
0-60mph: 2.9 seconds
Lateral g-force: 1.6 g
Chassis: Carbon fibre with aluminium honeycomb

Extreme engineering

How It Works breaks down the exterior of a car that's designed for a life in the fast lane

Windshield
A huge, swept panoramic windshield delivers optimal visibility in-car.

Wing
A dynamically movable rear wing ultimately allows downforce to be controlled by the driver.

Splitter
A cut-out splitter ensures that airflow reaches the rear diffuser during braking and promotes constant downforce.

Vents
Vents over the Agera R's wheel arches reduce drag and increase downforce.

Intakes
Large, tapered side intakes ensure the R's pressure point is behind its mass centre, adding directional stability at high speeds.

4x © Koenigsegg

"The entire building – including its artificial island base – only took five years to construct"

2 The seven-star super-structure

The Burj Al Arab hotel boasts a $650m, sail-inspired design and sits on its own man-made island

The statistics...

Burj Al Arab

Cost: £400m ($650m)

Rooms: 205

Floors: 70

Height: 320m (1,053ft)

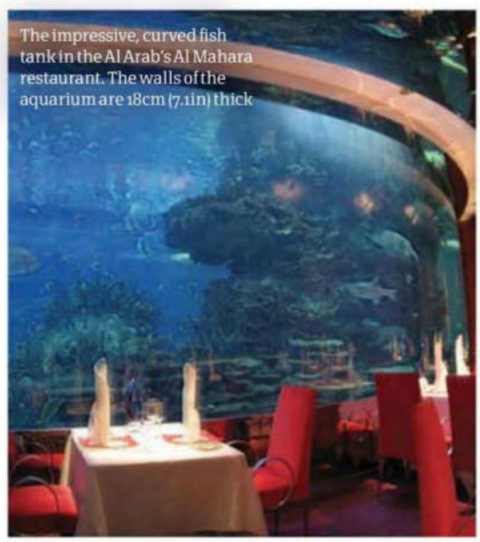
Total floor area: 111,500m² (1,200,000ft²)

A revolutionary new architectural design, the Burj Al Arab hotel in Dubai is currently one of the planet's most impressive buildings. Its engineers designed it to resemble the sail of a dhow sailing vessel, with two reinforced concrete wings acting as the building's V-shaped mast, and the sail consisting of the atrium's mainly glass rear curve.

A stunning building such as this is only made possible thanks to recent advances in concrete reinforcement, as well as the ability to manufacture lightweight steel – of which the Al Arab sports 9,000 tons – and strengthened, curved glass. Due to its construction on a totally artificial island, which was created by driving huge concrete piles into the seabed, an advanced foundation structure also needed to be realised, with the hotel resting on a honeycomb base; this grants staggering strength and also malleability for resisting constant shifts in the Earth's surface.

All of this is pretty impressive. It becomes astounding, however, when you factor in that the entire building – including its artificial island base – only took five years to construct. Speaking on its opening, an architectural critic said: "This extraordinary investment in state-of-the-art construction technology stretches the limits of the ambitious urban imagination."

Speaking of astounding, the hotel also comes with its very own gravity-defying helipad at the tip of the 'sail', so guests can come and go without ever touching the ground, as well as a restaurant with a floor-to-ceiling aquarium packed with tropical fish.



The impressive, curved fish tank in the Al Arab's Al Mahara restaurant. The walls of the aquarium are 18cm (7.1in) thick

1. DEADLY

M203
A launcher designed to attach to the M16 and M4 Carbine rifles, the M203 fires single-round 40mm (1.6in) ordnance to a range of 150m (490ft).

2. DEADLIER

M-32 MGL
A lightweight, multiple-round grenade launcher, the M-32 MGL can fire a maximum six 40mm (1.6in) grenades per cartridge up to 375m (1,230ft).

3. DEADLIEST

XM25 CDTE
A handheld grenade launcher that can fire a variety of 25mm (0.98in) programmable smart ordnance to an effective range of 700m (2,300ft).

DID YOU KNOW? A single XM25 CDTE grenade launcher would set you back $25,000 [£15,700]

The ultimate weapon

Weapons don't come much more devastating than the XM25 CDTE grenade launcher, aka the Punisher

US special forces teams have recently deployed the Punisher in Afghanistan

Think a Counter Defilade Target Engagement system (CDTE) sounds boring? Does it conjure up an image of a tool for deflating tyres? Well, think again. Because that system is actually the most technologically advanced weapon currently on the planet.

And what a weapon it is. The XM25 CDTE is a culmination of decades of engineering forged into an incredibly powerful tool that can change any warzone it is fielded in. It's a handheld semi-automatic grenade launcher that can propel a wide variety of munitions up to 700 metres (2,300 feet) and cause massive damage against any imaginable targets. Not excited yet? Well, this handheld grenade launcher can not only directly fire explosive rounds, but also program each wirelessly, and on the fly, to explode at a set distance or at a set time, to ensure it never misses its target. Sounds a little more impressive now, doesn't it?

Indeed, this weapon truly is a 'system' rather than a mere gun, with each unit equipped with an in-built ballistic computer, digital compass, fuze setter, environmental sensor array, laser rangefinder, 4x thermal sight with digital zoom and XM104 target acquisition and fire control chipset. All this is packed into a rifle that weighs less than 6.4 kilograms (14.1 pounds) – that's the equivalent of just three bags of sugar. Combine these components and you are ready to stir up a whole gunboat-load of trouble for enemy forces.

Are you facing troops dug in deep, sheltering behind reinforced cover or hiding within the ground? That's no challenge for the XM25 – simply laser the position with the Punisher's rangefinder, aim and watch a programmed round loop with pinpoint accuracy over the obstacle and then explode at the optimum moment in a devastating air burst.

Or perhaps you have a squad of enemy forces rumbling your way in an armoured personnel carrier? No problem, because if you select the XM25's armour-piercing ordnance, you have a weapon that can penetrate the APC's hull with ease.

The versatility of the XM25 CDTE is on a whole different level to any other weapon ever engineered and this is reflected in the US Army's decision to introduce 12,500 Punishers to its troops throughout 2012.

The statistics...

XM25 CDTE

Weight: 6.4kg (14.1lb)

Length: 749mm (29.5in)

Cartridge: 25mm (0.98in) explosive ordnance

Muzzle velocity: 210m/s (690ft/s)

Range: Up to 700m (2,297ft)

Feed: 4-round box magazine

Operation: Gas operated, semi-automatic

Electronics Ballistic computer, digital compass, environmental sensor, laser rangefinder

How the Punisher works

We examine the handheld weapon so explosive it could level your house with a single round

Magazine
The rifle comes with a four-round box magazine as standard, which can carry the weapon's wide range of ordnance types without any modification.

Laser
As well as the Punisher's 4x thermal sight and 2x optical sight, it is also equipped with a next-gen laser rangefinder. This allows distance to target to be acquired rapidly in the field.

Control
The XM25's XM104 control system is state of the art, allowing its user to program the rifle to set fired munitions to explode at a certain distance or after a set period of time. Desired round distances and times are automatically transmitted to each grenade.

Barrel
The rifle features a semi-automatic gas operation that propels rounds down the CDTE's rifled barrel at 210m (690ft) per second. The barrel's rifling is incredibly fine, as after a distance-set round has been fired, it tracks its own progress by measuring its total spiral rotations.

Ammo
The XM25 CDTE can fire a variety of programmable ordnance including: thermobaric, flechette, airburst, armour-piercing and door-breaching grenades.

"If you need to move a mountain then what you really need is the Krupp Bagger 288"

4

The mechanical monster

The world's biggest land vehicle, the Krupp Bagger 288 is larger than an Ancient Greek Titan and heavier than Titanic


The Bagger 288 can excavate 240,000 tons of coal or earth each day; that is the equivalent size of a football field dug to a depth of 30m (98ft)

© JaySef

If you need to move a mountain then what you really need is the Krupp Bagger 288, the world's largest and most awe-inspiring bucket excavator. And when we say large, we really mean titanic in scale, a behemoth and mechanical monster that dwarfs men, other vehicles and structures alike, as if they were all merely bugs.

This giant earth digger was designed by German company Krupp (now ThyssenKrupp) to literally hollow out mountains in Germany in search of coal, which it then excavates with savage efficiency, piling bucket after bucket of soil and rock into its auxiliary storage bins. From its huge containers, the material – hopefully containing coal or other valuable minerals – is automatically carried through its huge body and out on to massive conveyer belts which lead to a processing facility. To put its capabilities in context, the Bagger 288 can fill 2,400 coal wagons in a single day!

The statistics...


© ThyssenKrupp

Krupp Bagger 288

Height: 94m (311ft)
Length: 214m (705ft)
Chassis width: 46m (151ft)
Weight: 45,500 tons
Max speed: 0.6km/h (0.37mph)
Turning radius: 100m (328ft)
Power consumption: 16.6MW

Learn your way around the Krupp Bagger 288

We explore the machine so powerful it can sculpt the surface of the Earth at a whim

Power
Due to its vast size the Bagger 288 requires 16.6MW of externally supplied electricity to power its excavator, tracks, chassis and transmission.

Tracks
The 288's chassis sits on three rows of four caterpillar track assemblies, each 3.8m (12ft) wide. The large surface area of the tracks grants the Bagger a ground pressure of just 1.8kg/cm² (24.8psi).

Crew
It takes five people to operate the 288 and over 70 to move it. If the Bagger crosses any roads, once it is clear they must be totally rebuilt, as its insane weight crushes the concrete.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch the titanic Bagger 288 excavator at work!

www.howitworksdaily.com

DID YOU KNOW? US defence contractor Lockheed Martin became the first to purchase a D-Wave One in May 2011

The reason why the 288 doesn't deliver the material itself is due to its immense weight, tortoise-slow movement speed and colossal turning circle. That is not to say that the 288 is incapable of relocating itself – indeed, it frequently moves around stripmines in Germany – however movement remains a very cumbersome affair.

For example, in February 2001, the 288 had totally exposed all of the coal located in the Tagebau Hambach stripmine and therefore was no longer needed in the area. As such, it was deemed that the Bagger should be relocated 23 kilometres (14 miles) down the road to the Tagebau Garzweiler mine. While this short distance would have been covered by a standard road vehicle in a matter of minutes, the 288 took three weeks to complete the journey and it cost the operator over £6m ($9.9m). Further, over 70 engineers were needed at all times to ensure its safe passage, which necessitated it crossing the large Autobahn 61 motorway, the River Erft, a railway line and numerous roads.

Interestingly – and maybe the greatest engineering feat of the Bagger's construction – due to its designers specifying the 288's tracks with such a large surface area, the vehicle's ground pressure is – relative to its size – incredibly small, clocking in at under two kilograms per square centimetre (25 pounds per square inch). This small ground pressure means that the Bagger can traverse a wide array of terrains, including grass, gravel, earth and tarmac – nevertheless roads still need to be resurfaced in its wake.

The computing breakthrough

The D-Wave One quantum computer can solve problems a million times faster than today's supercomputers

The D-Wave One quantum computer – technically known as a 'quantum optimiser' – works differently to classical computers in many ways. However, the most important is its abilities to use superposition – to put bits of information into more than one state at the same time – and its restating of mathematical problems in terms of a Hamiltonian – which is essentially the energy of the forces that move particles about.

It does this by manipulating the states of quantum bits (qubits) to set up the problem that needs solving through the use of couplers and programmable magnetic memory (PMM). Once the problem has been set up within the system, the D-Wave One then determines the answer by naturally evolving its system into its lowest-possible energy state.

This evolution into a lowest-energy state – or the 'ground state' – is key to the operation, as it highlights the avenue D-Wave has used in its system. Indeed, the reason why the computer is called a quantum *optimiser* is that it arrives at this energy ground state adiabatically (without the release or input of heat within the system). It does this by cooling its circuitry to 20 millikelvin (272.98 degrees Celsius/459.36 degrees Fahrenheit; near absolute zero) and building it out of a material known as superconductor. In doing this, the D-Wave One can create a direct passage from the initial programmed system state (ie the problem) to the system ground state (ie the answer) naturally and incredibly quickly, considering a range of different permutations simultaneously.

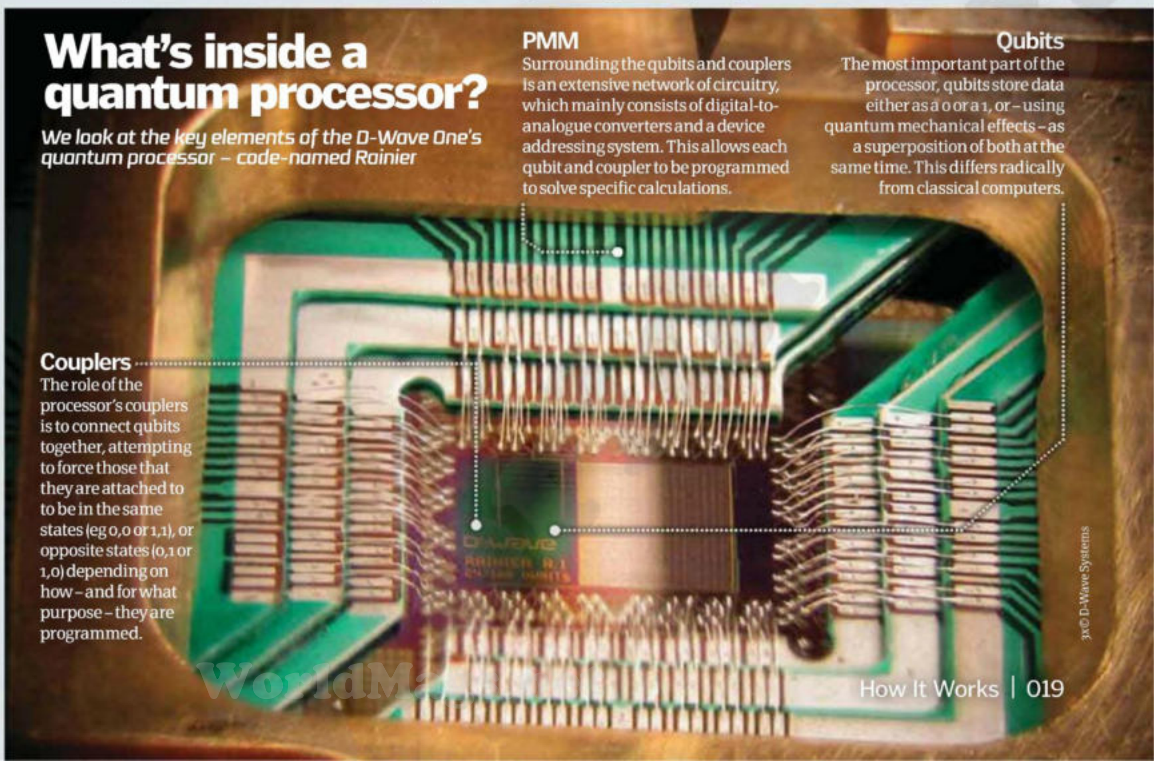
In essence, the D-Wave One reaches answers to questions by 'tunnelling' through an energy landscape directly to the landscape's lowest-possible energy state. This can be likened to the passage of a golf ball on a golf course into a hole. The initial system's state is the golf ball on a tee, the energy landscape the hills and valleys of the course, and the hole the ground state. To reach the hole (the answer) in a classical computer, the system – non-adiabatically – moves the ball over the obstacles into the hole. In the D-Wave One, meanwhile, the ball tunnels through the hills and over the troughs directly into the hole.

The D-Wave One is already demonstrating the immense possibilities of quantum computing, but it's clear that there's still a lot more potential to revolutionise computing.

The statistics…

D-Wave One

Material: Superconductor
Qubits: 128
Couplers: 352
Junctions: 23,360
Temperature: 20mK (272.98°C/459.36°F)



"While an F-35 gets from London to Rome in 55 minutes, the Falcon could do London to Sydney in 50"

A Falcon HTV separates from a Minotaur rocket to begin its re-entry phase

6

The Mach 20 hyperplane

The Falcon HTV obliterates the speed of sound tenfold and is capable of reaching – and exceeding – the 13,000mph mark

Let's run some numbers. Mach 1 – considered the speed of sound at standard sea level conditions – is 1,225 kilometres (761 miles) per hour. As such, Mach 1.6 – the maximum operating speed of the cutting-edge F-35 Lightning II fighter jet – is roughly 1,930 kilometres (1,200 miles) per hour, a speed that would get you from London to Rome in just under 55 minutes. That's pretty fast, wouldn't you agree? Especially considering the standard passenger jet takes almost three times that to make the very same trip.

Wrong! Actually, it's not fast at all. In fact, when you place the Falcon HTV into this little competition, it makes both the F-35 and the passenger jet look like the Wright Flyer on its first wobbly test-flight.

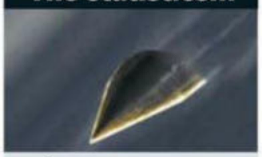
Why? Once again the numbers reveal all. The Falcon hypersonic test vehicle (HTV) has been engineered to travel at speeds of Mach 20 and above – Mach 20 equating to roughly 20,900 kilometres (13,000 miles) per hour. As such, while that F-35 gets from London to Rome in 55 minutes, on the Falcon, you could hop across the Earth from London to Sydney, Australia, in 50 minutes.

All this comes courtesy of a programme dedicated to advancing humankind's understanding and critical knowledge of the technologies needed to generate a vehicle capable of sustained hypersonic flight. The HTV project – which at this time has consisted of both the HTV-1 and HTV-2 aircraft – is achieving these goals via a series of test vehicles that, once carried to orbital speeds on the back of a Minotaur IV Lite rocket, are released to accelerate up to – and over – 20,900 kilometres (13,000 miles) per hour.

The role these vehicles then play is best described as large data trucks – full-scale hypersonic aircraft equipped with a host of sensors to collect data during the high-speed operating envelope. This information, which includes feedback on the aircraft's aerodynamics, aerothermal effects, critical guidance and navigation and control mechanisms is then relayed in real-time back to DARPA (the Defense Advanced Research Projects Agency) for processing and analysis. The end goal of all this hypersonic flight and data acquisition is to attain a level of competency in which an armed hypersonic fighter aircraft can be built that could strike any target anywhere on the planet in less than two hours.

So far, the Falcon HTV vehicles have returned a swathe of hypersonic flight information. This includes verification of the test vehicles' reaction control system (RCS), hypersonic communication system, GPS – an amazing feat considering that the Falcon can be travelling at over 5.8 kilometres (3.6 miles) per second, and the necessary thermal-protective material properties needed for travelling at these immense speeds in the Earth's atmosphere.

The statistics...



Falcon HTV

Height: Classified
Length: Classified
Weight: Classified
Max speed: >20,920km/h (>13,000mph)

2x © DARPA

The engineeri

The Golden Gate Bridge defied what was conceived as possible to create a link between San Francisco and Marin County

When it was completed back in 1937 the Golden Gate Bridge boasted the longest suspension bridge main span in the world, covering 1,280 metres (4,200 feet). Not only this, but by traversing San Francisco Bay, this marvel defies notoriously high wind speeds, blinding fog, powerful tides, a channel depth of 113 metres (372 feet) and a lot of difficult terrain. Indeed, for these reasons, it is not surprising that commentators at the time of its conception stated it was an impossible venture.

Naysayers aside, it did conquer the strait and since it has linked San Francisco to Marin County. This was achieved by three main factors: the choice of bridge type; the materials used; and advanced (for the time) construction techniques.

The bridge's design is a suspension, truss arch and truss causeway variant. The suspension element is key to its ability to sustain a 1,280-metre (4,200-foot) main span without support, with two towers taking its massive 123,000-ton load via two main cables. The cables are connected to each end of the bridge – and intermittently along its span via finer vertical cables – into each side of the strait via huge concrete braces; each main cable comprises 27,572 strands of steel.

The truss arch and causeway both deliver flexibility in terms of the main span's ability to move. This is very important considering the weight and shifting nature of its load (ie a varying number of moving vehicles) and also the differing temperature conditions; indeed, the main span can move vertically through five metres (16 feet) due to thermal expansion. This is why the main span is arched towards a central apex, a shape that accounts for this motion and ensures the structure remains stable at all times.

Lastly, the Golden Gate Bridge remains a great engineering feat due to its advanced construction techniques. The adoption of new advances in metallurgy means it not only features galvanised and carbon steel (both main cables are made from the latter), but is also coated with a lead-based primer and topcoat and, later, a zinc silicate primer and vinyl topcoat to mitigate against rust.

5 TOP FACTS THE GOLDEN GATE BRIDGE

Ferry inconvenient
1 Before the Golden Gate Bridge was built the only way to cross from San Francisco to Marin County was by boat. A regular ferry service began in the 1840s.

Naysayers
2 Prior to the bridge being built, many commentators stated it would be impossible to do so, with the strait too deep and its winds too fierce for any passage to be practical.

Maintenance
3 Today, a large team of 38 painters are permanently employed by the bridge's operators to maintain its paintwork, patching up areas that become heavily corroded by the sea air or otherwise damaged.

Fool's gold
4 The bridge's distinctive colour is a shade of vermilion called 'international orange'. It was chosen to complement the natural surroundings and enhance its visibility in fog.

Big birthday
5 The Golden Gate Bridge celebrated its 75th birthday on 27 May 2012, on which it played the starring role in a city-wide festival, in a nod to the Golden Gate Bridge Fiesta of 1937.

DID YOU KNOW? The speed limit on the Golden Gate Bridge is 72km/h (45mph)

ing icon

The statistics...

Golden Gate Bridge

Material: Steel
Height: 227.4m (746ft)
Length: 2.7km (1.7mi)
Width: 27.4m (90ft)
Clearance: 67.1m (220ft)
Daily traffic: 120,000 vehicles

The Golden Gate Bridge close up

How It Works analyses the key components of the planet's most iconic bridge

Towers
The towers soar 227m (745ft) above the water and 152m (499ft) above the roadway. Each takes a load of 61,500 tons from the cables.

Cables
The roadway and walkway are suspended by two huge cables that pass through the bridge's two main towers. Each cable is made up of 27,572 strands of wire.

© Kitchen/San Francisco

Gates
Entrance to the bridge is free on the northbound carriage, but southbound traffic pays a toll. Motor vehicles pay $6, while vehicles with more than two axles pay $2.50 per axle.

© Roulex

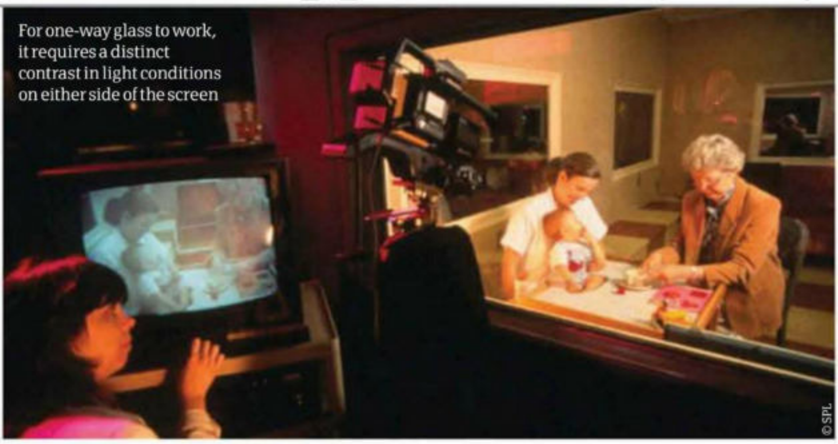
Walkway
Down either side of the roadway are civilian walkways, which are separated from the passing traffic by a reinforced steel barrier.

© Bill Ebbesen

Roadway
The bridge is a truss arch and causeway design. As such, the roadway is curved towards a central apex so it can adapt to both the temperature and the variable weight of traffic.

© Tewy

Braces
Due to the immense weight of the roadway, the supporting cables are tightly locked within gigantic concrete braces located at either end of the structure.



For one-way glass to work, it requires a distinct contrast in light conditions on either side of the screen

One-way glass

How is it possible to make one side reflective and the other transparent?

The secret of one-way glass is that it only works under certain conditions. One side of the glass is covered with a super-thin reflective layer, called a half-silvered coating. It's so thin that about half of all light hitting its surface is reflected while the rest is let through. When placed between two rooms – one brightly lit and one dark – the mirrored side has plenty of light to reflect, giving it the appearance of a normal mirror. On the dark side, however, there's enough light allowed through by the half-silvered surface to see the other room perfectly. The effect is ruined if the lights are switched on in the dark room, because the surface isn't opaque so the light, and occupants, can be seen from the other side.

How automatic taps work

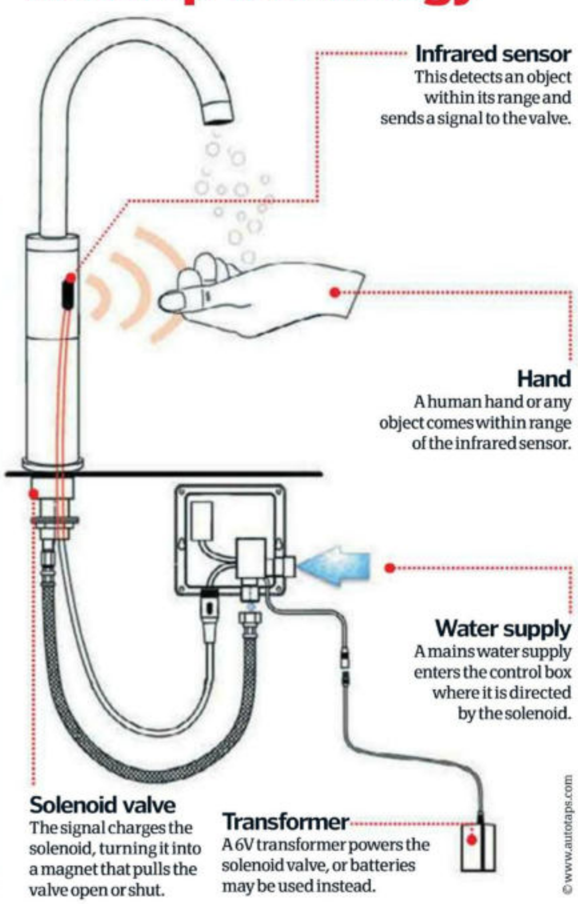
How autotaps differ from classic faucets and why they're better

It's often the case that inventing technology that makes our lives easier has some kind of karmic effect on the planet. Like the combustion engine, for example: millions of us get from A to B in a car every day, yet it's one of the major contributors to global pollution.

Not so with automatic taps. This relatively recent invention enables us to pass our hands under the spout and immediately douse them in water, without twisting a knob. An infrared sensor detects when an object (eg hands) is in front of the tap and sends an electric signal to a solenoid valve. This wire coil acts as a magnet when a current is passed through it, lifting a valve into the range of a permanent magnet that holds it open, allowing water to flow. Once the object is removed, the sensor sends another signal to the solenoid valve, which reverses its polarity and pulls the valve shut, stopping the flow of water.

Automatic taps are not only more economical and eco-friendly but they're also ideally suited to hospitals, where germs can easily be transferred via communal surfaces.

Autotap technology

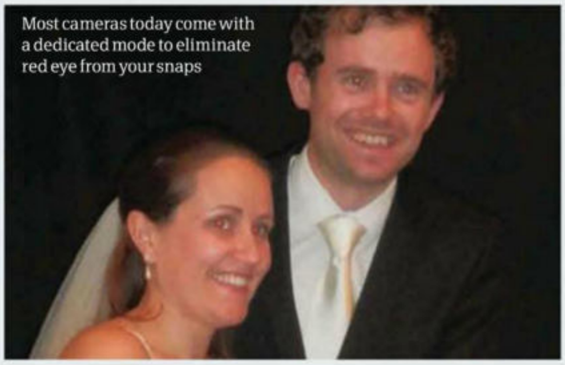


How is red eye prevented?

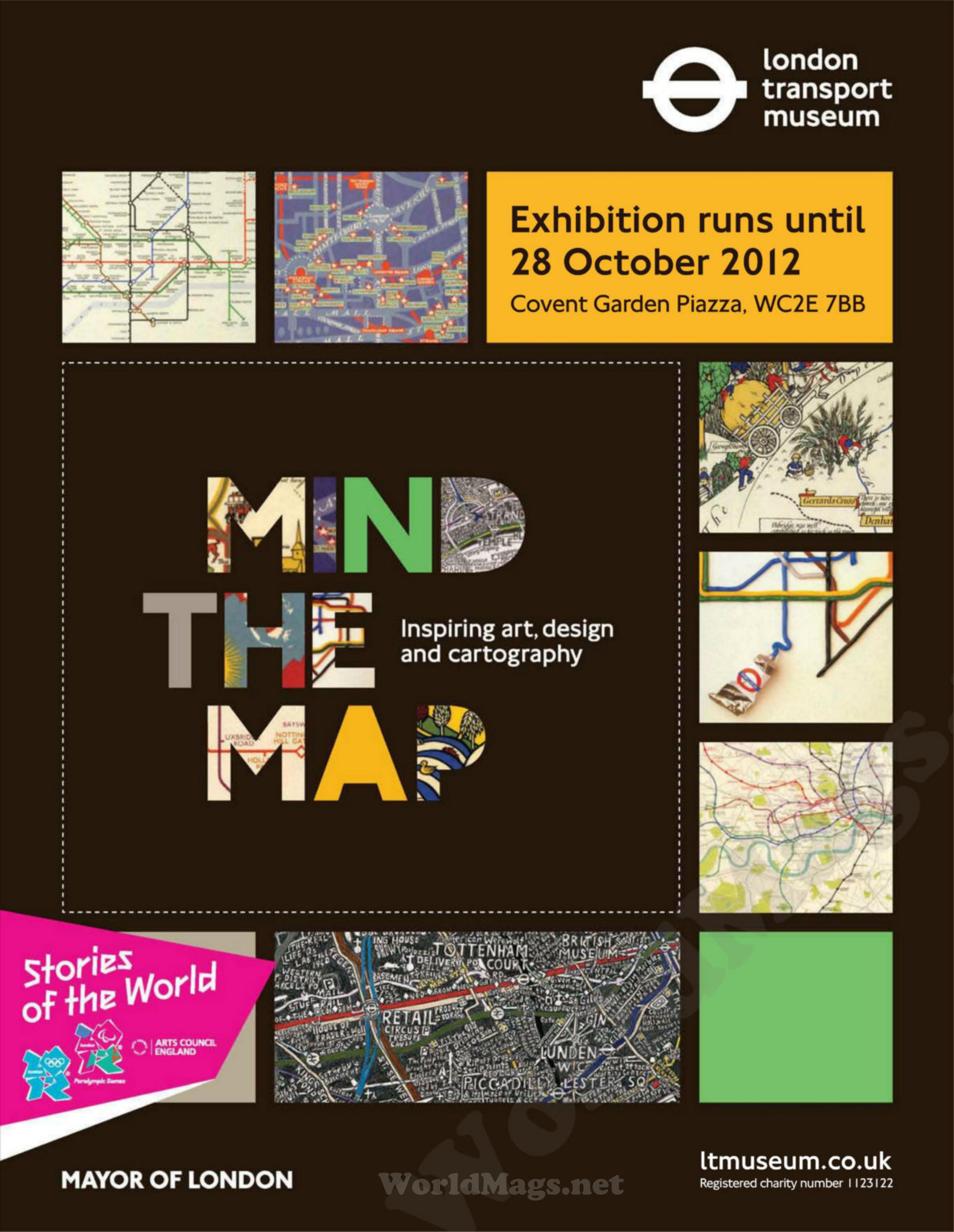
What tricks do modern cameras employ to remove pesky 'devil eyes' from portraiture photography?

In many nocturnal animals, a reflective layer called the tapetum lucidum at the back of their eyes reflects light like a mirror, helping to enhance eyesight at low levels of illumination. This doesn't exist in humans, so the flash from a camera hits the retina and is sometimes strong enough to cause a red glow, a result of light bouncing off the blood vessels at the back of the eye.

To counteract this effect, some cameras include a red-eye reduction mode. This works by triggering the flash twice in rapid succession: once for the actual photo and once just before. The first of the flashes will cause the pupils to contract, significantly reducing the amount of light entering the eye and, more often than not, eliminating red eye in the actual photo that quickly follows.



Most cameras today come with a dedicated mode to eliminate red eye from your snaps



london transport museum
Exhibition runs until 28 October 2012
Covent Garden Piazza, WC2E 7BB
MIND THE MAP
Inspiring art, design and cartography
Stories of the World
ARTS COUNCIL ENGLAND
Paralympic Games
MAYOR OF LONDON
ltmuseum.co.uk
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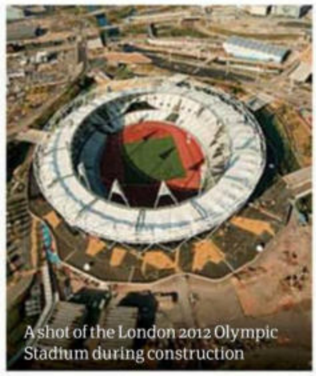
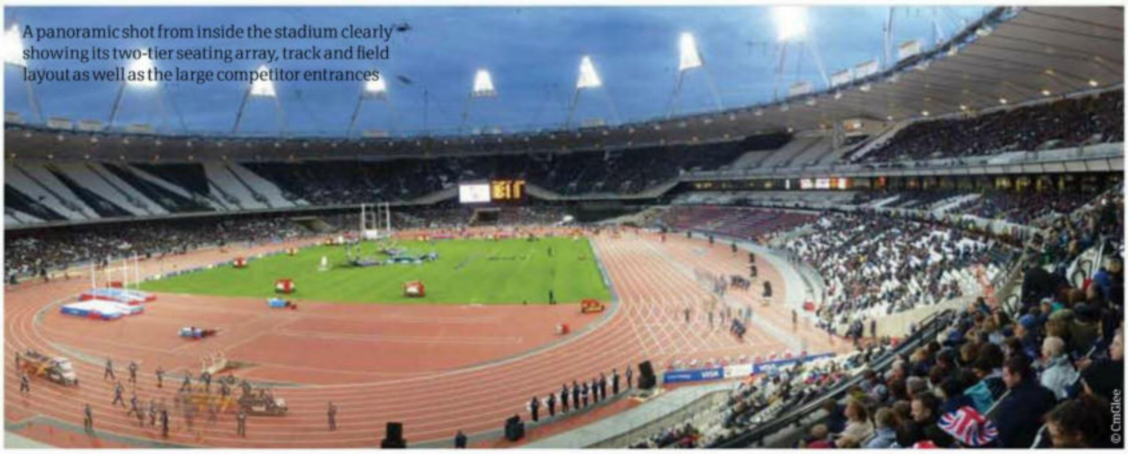
“A good example of this fluidity is in its adoption of a completely removable second tier of seating”

Inside the London 2012 Olympic Stadium

Discover how it was built, the materials that were used and which features make this the best-ever Olympic arena



A shot of the London 2012 Olympic Stadium during construction



A panoramic shot from inside the stadium clearly showing its two-tier seating array, track and field layout as well as the large competitor entrances

© CmGlee

Let’s kick off with some fast facts. The London 2012 Olympic Stadium was created by the excavation of 800,000 tons of soil – soil that was then reused in construction throughout the wider Olympic Park. The arena also took only 10,000 tons of steel to create, which is significantly less than any other Olympic arena built to date – indeed, the entirety of the impressive top ring of the stadium was forged out of pre-existing, surplus gas pipes.

The stadium’s roof covers a huge 67 per cent of the seating within and was constructed out of phthalate-free polyvinyl chloride (PVC), which not only led to it being one of the most cost-effective stadium roofs in history but also one of the most environmentally sensitive. Despite these impressive construction techniques and materials, these are only a few of the reasons why the London 2012 Olympic Stadium is one of the best ever conceived.

A bigger, and arguably even more important, element of the arena is its construction to a super-flexible and fluid design brief, with the central venue split into three key sections: the track/field, lower-tier seating and upper-tier seating arrays. This clear segmentation of the huge, 80,000-seat stadium is due to an emphasis on sustaining its usability after the 2012 Games has finished, with key parts able to naturally evolve to suit a wide range of future events.

A good example of this fluidity is in its adoption of a completely removable second tier of seating, which despite providing a vantage point this summer for 55,000 spectators per event day, can be completely removed once the tournament is over, granting the local authority or private buyer a great deal of freedom in any re-specification. Indeed, it has been recently announced that the stadium will be adopted for the IAAF World Championships in 2017.

This forward thinking in terms of future evolution is also demonstrated in the design of the Olympic Stadium’s concourse and convenience facilities, with the former granting a 360-degree freedom of movement for spectators and athletes around the vicinity of the arena, and the latter providing a host of facilities all positioned outside it; toilets, merchandise and catering booths, etc, are largely located in external pods.

All this sustainability and legacy, while impressive, has not however compromised the stadium’s outfitting, with some cutting-edge technology and advanced facilities on display.

Within the stadium two custom-built Panasonic TV screens have been installed to show key events, scores and information to spectators – the screens each measure an insane 1,836 centimetres (723 inches).

In addition, a dedicated high-tech medical support suite has been integrated within the lower tier’s infrastructure, enabling athletes to receive the best medical assistance on site. Also, athletes will have access to a dedicated 60-metre (197-foot) warm-up track and spectators will be able to access the stadium’s concourse through five custom-designed bridges.

© Populous

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch a time-lapse video of the complete build

www.howitworksdaily.com

DID YOU KNOW? Work on the Olympic Stadium began in May 2008 and finished in March 2011

The statistics...

© EG Focus/Bald Boris

London Olympic Stadium

Ground breaking: 2007

Opened: 2011

Location: Stratford

Surface: Track and field (grass)

Cost: £486m ($765m)

Capacity: 80,000

Curtain
A fabric curtain encircles the stadium's upper-mid structure providing shelter for spectators on the upper tier.

Track/field
At the centre of the stadium lies its track and field, on which the athletes will compete.

Concourse
At the ground level the concourse sweeps a full 360 degrees around the arena, providing visitors with plenty of room to find their entrance and relax between events.

Columns
The stadium is supported by a vast ring of concrete and steel columns, which are located within the inner concourse.

Pods
Surrounding the concourse is a series of pods; these supply a large portion of the stadium's catering and merchandise.

"Webcam sensors, lenses and chipsets tend to be very small and simple"

Web cameras in focus

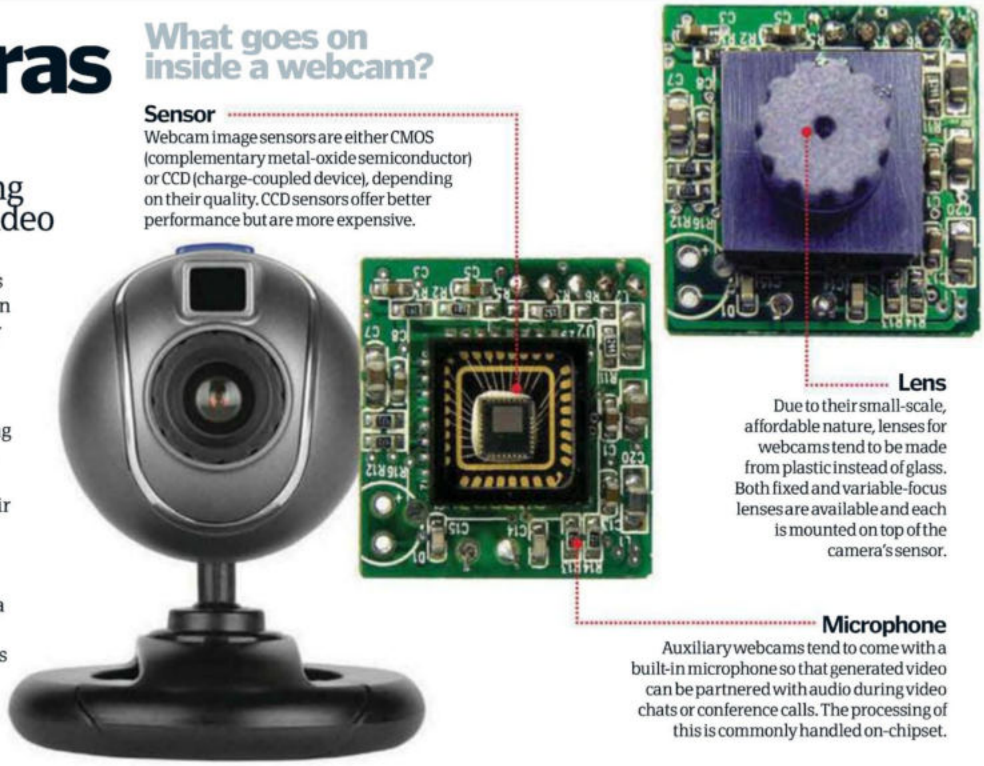
How these miniature recording devices capture images and video

A web camera is a small video camera designed to record and transmit images and/or video to a computer or network in real-time, with feeds typically sent over an Ethernet or Wi-Fi internet connection.

Unlike full-scale video cameras, webcams are designed to only capture and record video over a relatively small area, typically with their focus being a user positioned directly in front of them. As such, their sensors, lenses and chipsets tend to be very small and simple, and are selected according to their low weight and cost to manufacture. Further, recorded images and video are transmitted and stored remotely, not on the camera itself.

Standard webcams today are both connected to a computer and also powered by a USB cable, which grants a fast enough transfer rate to transmit images and video live and also helps reduce the camera's weight even more, as no internal battery is needed. Many laptops also have webcams built in.

What goes on inside a webcam?



Fire suits explained

How do these space-age-looking clothes shield firefighters from deadly flames?


A fire suit comprises three main layers that, together, keep the firefighter within safe from harm

Fire suits, which are sometimes known as 'bunker gear' and 'turnout gear', consist of several protective layers of heat-resistant synthetic materials called aramids. These suits must not only protect the wearer from obvious extreme heat and burns, but they must also allow air transfer (to let cool air into the suit and expel body-heated air away), as well as preventing moisture buildup inside the gear itself. There are three main layers to a fire suit: the outer shell, the moisture barrier and, lastly, the thermal layer.

The silver-coloured outer shell seen in these images here must be tough enough to withstand splashes of molten metal, yet flexible enough to enable the wearer to remain mobile. This layer is often a combination of carefully woven fibres made of a fire-resistant variant of Kevlar called NOMEX. A tight weave ensures that the material resists ripping during often strenuous firefighting activity. It also offers a degree of moisture deflection.

Below the outer shell comes an essential moisture barrier, which prevents liquids and chemicals from passing into the suit. This material consists of a breathable fabric such as Breathe-Tex, sewn in with the NOMEX/Kevlar blend.

Third is a strong thermal layer made from Kevlar-based fibres woven into the material. Flames won't penetrate through this layer and it also absorbs around three-quarters of a fire's heat. The temperature of a typical fire ranges from 400-800 degrees Celsius (750-1,470 degrees Fahrenheit).

5 TOP FACTS SAUNAS

A Finnish beginning

1 The original Finnish saunas were pits dug into the ground in which a fire was created to heat stones. By throwing water over them, steam could be generated to increase the overall pit temperature.

Wood

2 During the Industrial Revolution in the late-18th century saunas evolved to use a metal woodstove with a chimney. This enabled temperatures to be increased up to 90°C (194°F).

Modern

3 Modern saunas can approach 100°C (212°F) as they have systems to control their humidity. If this wasn't controlled people could be scalded by the air temperature.

Sauna vs steam room

4 Although saunas and steam rooms can sometimes be confused, they are different. Saunas can produce both dry and wet heat, while steam rooms can only produce wet heat.

Splashing out

5 The best saunas come equipped with a dedicated plunge pool or cold showering unit. These are recommended to cool the body back down to normal after the intense heat.

DID YOU KNOW? Squibs were used in the 19th century to break coal away from worthless rock in mines

Inside saunas

The science of these sweat rooms unravelled

A sauna is a small, enclosed room – usually lined with wooden panels – used by people to experience two main kinds of heat session, the goal of both being to induce sweating and the cleansing of the skin. The two main types of heat generated in saunas are dry and wet, which are differentiated by the sauna's humidity level. Dry-heat saunas have very hot temperatures (approaching a blistering 100 degrees Celsius (212 degrees Fahrenheit) and very low humidity levels – controlled by an automated system. Wet-heat saunas, on the other hand, have lower temperatures, but higher humidity levels, acting more like a steam bath.

The heat in both cases can be generated in a variety of ways, however the most common practice is to use a stone fire. These are heating elements covered with large smooth stones that, when heated, can have scented water thrown over them to generate large quantities of vapour. These are popular as the heat generated by the stone fire can be spread out more evenly through the water vapour than through standard air convection.

Historically, saunas were pioneered in Finland, where they have become a national tradition. However, the first recorded evidence of a sauna comes from Ancient Greek historian Herodotus, who describes in *Histories* how the inhabitants of Scythia in central Eurasia used to throw water and hemp seeds on heated stones to create a hot, intoxicating steam.

A modern sauna at a health spa with traditional wood-panelled interior

A typical modern squib with a water-protective lining

What is a squib?

The miniature explosives often used in the movies explained

A squib is a small explosive device used to generate a mechanical force or visual effect. Squibs usually resemble a small stick of dynamite or layered fabric sheet, with each style containing a small quantity of explosive substance along with a central detonator.

Squibs can either be detonated via a traditional slow-burning fuse – like the one shown in the image above – or by a wired connection to a remote electronic trigger, the latter being more common today due to increased safety standards.

Typical uses of squibs include separating different materials – for example, in coal mines, where small detonations can break away valuable coal from worthless rock, and as a controllable pyrotechnic. Squibs can simulate explosive effects for theatre and film productions without the need to use high-powered explosives, which are a lot more dangerous and expensive.

Historically, squibs were originally constructed from tubes of parchment and were filled with black powder. These primitive squibs did not have the insulating, water-resistant coating that they do today and, as such, if they got wet they would not function. This is where the common phrase 'damp squib' originates and why it is used to indicate that something has not worked correctly or to its maximum potential.

"Everything is prepared in advance so camera operators can concentrate on moving, composing and zooming"

Broadcasting live sports events

Much like any live performance, the secret to a successful live sports broadcast is preparation

Long before the sportspeople enter a venue, the broadcasting crews have set up, tested, rehearsed and rehearsed again.

The entire broadcast team practises with a run-through. During the broadcast, the output picture must look coherent whenever the vision mixer switches from camera to camera. To match the pictures, the vision engineer runs a 'lineup' before the event – all the cameras point at a greyscale chart and are adjusted for white balance and exposure.

Everything is prepared and pre-set well in advance so the camera operators can concentrate on moving, composing, focusing and zooming. Everything else is controlled remotely. The expensive professional cameras are fixed to tripods or trolleys, or handheld using a stabilisation rig like 'Steadicam'. With the director orchestrating the team via headsets, the cam ops' experience will greatly dictate the results.

In the mobile broadcast truck, or location studio, the director, vision mixer and graphics editor co-ordinate the output. In a separate area, the sound team prepare and mix the audio. They usually work in a well-insulated booth so they can accurately monitor the sound, without interference from the noise of the crowd outside or the whirr of air-conditioning, etc.

Many sports events use infographics to display team info, match data and so on. These are all pre-set and co-ordinated with the official results system at the venue. On the monitor, a camera operator can check a composition fits with the graphics by viewing the output as either 'clean' or 'dirty': clean is the picture by itself, while dirty is the picture plus any graphics.

But what happens if there's a problem, such as a camera failing, a race being delayed, or a more serious situation such as a terrorist attack? Commercial channels can switch to an advert break. For non-commercial channels like the BBC, this is when the skill of the presenters is tested as they talk to 'fill in' while the situation is resolved. This will have been rehearsed and there may be a piece of emergency video standing by just in case it's needed.

How 'live' is live? As anyone who lives near a stadium or similar venue will tell you, the delay for a true live broadcast is just a few seconds: they will hear the roar of the crowd just shortly before they see the triumphant event on their television. Some 'live' TV shows build in a longer delay, from a few extra seconds up to 15 minutes so they can broadcast events which occur simultaneously – getting a chance to remove bad language, for instance, in this interim period.

Outside broadcast vans enable broadcasters to transmit footage from almost any location away from the studio

Live TV transmission step-by-step

To deliver crystal-sharp

Step 1
Professional camera

Operated by a human or by remote control. Camera operators have a headset for communicating with the director and a cue light to indicate their footage is the picture being broadcast. Cameras are set up in advance by assistants. Operators may pepper their focus and zoom controls with markers made from tiny triangles of electrical tape so they can quickly move to rehearsed settings.

Step 2
Link to CCU

The data from the camera's processor is sent to the camera control unit (CCU). For live sports, broadcasters often use wireless microwave links. If the camera is connected via cables, HD signals are sent down fibre cables, while SD signals are sent via triax cables. Many venues have 'tie-lines' – fixed points built in to the venue's infrastructure so cables can be plugged in and data sent to the CCU.

Step 3
Camera control unit (CCU)

This is effectively the 'brain' of the camera. Vision engineers monitor the live picture and 'ride the levels' continuously to make sure the white balance and exposure is set correctly for all the cameras. The engineers transmit requests to the CCU by remote control, which in turn alter the camera settings.

Step 4
Digital interface

Data from the cameras is processed at a digital interface, which transforms it into robust signals that can then be transmitted over large distances without losing any of the quality.


Right: An operator's view of a fixed camera

KEY DATES
TV BROADCASTING

1924-1925 John Logie Baird invents and demonstrates live TV broadcasting.

1936 The Olympics in Germany is the first live sports transmission (right), transmitted by cable and viewed in Berlin and Leipzig.


© Telefunken-Bild, Berlin

1966 At the FIFA World Cup in England, 32.3 million watch the world's first live sports broadcast in colour.

1975 The UK's first live sports broadcast from abroad is Ali and Frazier's 'Thrilla in Manila' fight.

2006 The FIFA World Cup in Germany is the world's first live sports event broadcast in HD.

2010 Sky broadcasts a football match between Arsenal and Manchester United live in 3D to nine pubs in the UK.

DID YOU KNOW? When London hosts the 2012 Games, the BBC will broadcast around 2,500 hours of live TV

Pro vs consumer cameras

Lenses
■ Consumer cams have a built-in lens whereas pro cams have interchangeable lenses (wide-angle, telephoto, etc). For filming drama, cameras may use fixed focal-length lenses because the action is controlled; for unpredictable sports events, meanwhile, cam ops select lenses that allow them to respond to varying conditions.

■ Pro lenses are larger and more expensive because they're precision-made from thick, scratch-resistant glass assembled in a dust-free environment.

Zoom
■ Consumer cams usually measure zoom as 4x, 8x and so on, because it's easier to understand.

■ Pro cameras, in contrast, have stronger and more precise zoom lenses, measured in millimetres.

Chip
■ Consumer cams often have just one CCD (charge-coupled device): the silicon chip which converts light to digital signals.

■ A professional camera will have a minimum of three CCDs – one each for red, blue and green light. This extra information means a clearer picture capable of good resolution at larger sizes. Some pro cams use CMOS (complementary metal-oxide semiconductor) chips, another method of capturing data which requires less off-chip circuitry to process the data than a CCD.

Presets
■ Consumer cams don't usually have the option to create their own presets for different conditions.

■ Pro cams allow the operator to construct and save settings for different conditions, which in the future can be accessed at the touch of a button.

Versatility
■ Consumer cams usually have just one method of recording, while pro cams are adjustable.

■ Professional cameras can record in PAL (UK format, 25 frames per second) or NTSC (USA format, 30 frames per second); all the settings can be manually varied and the data-rate can be altered too. Pro cams can produce super-clear slow-motion playback with a frame rate of 50 fps, or even 100 fps.

HD and 3D
■ These new developments require cameras to capture more information. Standard definition (SD; ie 704 x 480 pixels) has now been replaced by high definition (ie 1,920 x 1,080 pixels) in all pro cams and most consumer cams. You need an HD-compatible television or computer in order to play HD video, otherwise it's compressed to SD.

■ Pro cams are now available with a super-high definition of over 4,000 pixels. Why bother with these new formats? They are especially good for sports viewing – the extra-fine resolution of HD means viewers can identify fast-moving players in wide shots, and 3D images communicate every detail of the action such as the distance between finishers in a sprint or the length of a javelin throw.

video to your TV, broadcasters use a complex array of technology

Step 5
Mobile broadcast van, or location studio, featuring:

Director Orchestrates the output – instructs the camera operators via their headsets and decides which camera picture to broadcast.

Vision mixer Follows director's instructions on what to focus on and image treatment, etc.

Sound editor The sound editor mixes audio 'on the ground' and from commentators.

Graphics Pre-set graphics are co-ordinated with the venue's results system and added to the output picture before transmission.

Step 6
Output sent

The sound, camera pictures and graphics are sent via cable to the 'sat truck' (for an outside broadcast) or master control room (if the directing gallery is in a studio). The signal is then sent to the broadcaster's transmission control centre, often via satellite but increasingly via a super-fast, high-quality internet connection.

Step 7
Live transmission

The broadcaster's transmitter sends the signal by electromagnetic wave to transmitters across the country (and via satellite to the rest of the world). The transmitters then broadcast the signal to homes.

Step 8
Watched by viewers

The digital signals are received at the viewer's aerial, then decoded and played by a TV so the viewer can enjoy the event, often with a better view than the audience at the venue. For a true 'live' broadcast, the delay will be just a few seconds.

What makes an Olympian?

Welcome to... SCIENCE

The Olympics are more than your average sporting contest: they're a celebration of the very best in human ability – but how do world champions differ from the rest of us? Also this month we discover how steel can be strengthened by galvanisation and how the liver keeps the body free of nasty toxins.

LEARN MORE

Olympian anatomy

Brain
Whether a runner is sprinting 100 metres (328 feet) or a pentathlete is guiding their horse, with years of training the brain of an Olympian changes and grows in harmony with other physical developments.

Skeleton
As a part of any physical training, bones strengthen with the stresses that muscles place upon them. Caucasians tend to have light bones while Polynesians naturally have a higher bone density, which can be genetically advantageous for certain sports.

Cardiovascular system
A strong heart and big lungs mean an athlete can last a long time in any event. A high red blood cell count will increase oxygen delivered to the muscles and a good circulation means oxygen will get where it's most required.

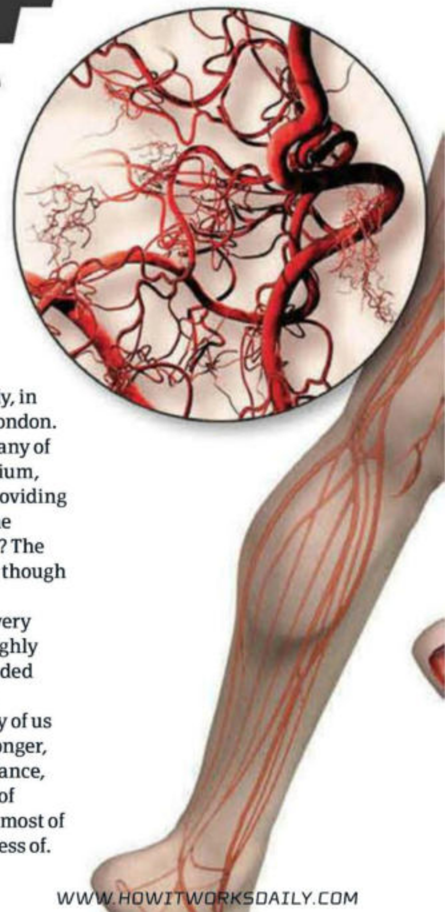
ANATOMY OF AN OLYMPIC ATHLETE

How do these real-life superhumans differ from your average Joe?

When we talk about superhumans, shooting lasers and turning invisible aside, there's a process of comparable feats that we normally run through. So, for example, the average guy might be able to sprint at 29 kilometres (18 miles) per hour but Superman can travel faster than a speeding bullet (roughly 1,300 kilometres/800 miles per hour). Similarly, a strong person might be able to lug a 70-kilogram (150-pound) canister around a pub, but in comparison The Thing could tow a 14,000-kilogram (31,000-pound) double-decker bus.

These are feats of fantasy, but we don't have to look to the world of fiction for truly astonishing human physical acts. In fact, a lot of sportspeople capable of testing the boundaries of the biological machine that is the human body are gathering this July, in the 2012 Summer Olympic Games in London.

So what is it exactly that's stopping any of us from rolling up to the Olympic Stadium, stepping up to the starting line and providing a serious challenge to Usain Bolt for the 100-metre (328-foot) sprint gold medal? The answer might seem obvious, but even though we're made of the same fundamental building blocks, Olympians are built very differently. Think of their bodies as highly specialised machines that have upgraded themselves through years of training, elevating them above the vast majority of us to become significantly faster and stronger, react quicker, last longer, improve balance, accuracy, dexterity and endure levels of self-inflicted physical discomfort that most of us would quickly buckle under the stress of.



Muscles
These can be divided into two main groups: fast-twitch fibres produce power and are great for sprinters and power lifters; while slow-twitch fibres contract more slowly but are more efficient, making them more suitable for endurance athletes.

An Olympian versus you!

Everyman
Occupation: Office worker

Wake up 0700
Breakfast:
Bowl of cereal and juice (300kcal)

Go to work 0830
Sit down
Answer telephone
Type documents
Walk to printer
Drink coffee (40kcal)

Lunchbreak 1300
Chicken sandwich
Crisps
Chocolate bar
Soft drink (800kcal total)

Finish work 1700

Gym 1800
5km (3.6mi) run

Dinner 1900
Jacket potato with tuna mayo and salad (500kcal total)

Relax at home 2000-2300

Bed 2300

Michael Phelps
Occupation: Swimmer (Olympic gold medallist)

Wake up 0630
Breakfast:
3 x fried-egg sandwiches
3 x chocolate-chip pancakes
5-egg omelette
3 slices of French toast
Bowl of grits (4,000kcal total)

Go to the pool 0800
2.4km (1.5mi) warm-up
4.1km (2.5mi) mixed strokes
Warm-down

Lunchbreak 1400
0.5kg (1lb) pasta
2 x ham-and-cheese sandwiches
Energy drinks (4,000kcal total)

Rest 1430

Go to the pool 1700
2.4km (1.5mi) warm-up
1km (0.6mi) mixed strokes
Warm-down

Finish training 2145

Dinner 2200
0.5kg (1lb) pasta
Large pizza
Energy drinks (4,000kcal total)

Bed 2300

Fuel: we all need it, but athletes need several times the calorific intake of the average person to sustain them during training

© Amadscientist

"Usain Bolt smashed his own world record in Berlin three years ago with a blistering 9.58-second run"

Super-human abilities

Football
You often hear people referred to as 'football geniuses', and there's more truth in that than you might at first think. Top-flight footballers are mental strategists akin to brilliant chess players.

Athletics
Runners need more fast or slow-twitch muscle fibres (depending on the event), throwers need core strength and hand-eye co-ordination, while jumpers need flexibility and leg strength.

Swimming
Swimmers with longer bodies and a bigger arm span than height, plus big hands and feet to propel them through the water, tend to perform better than others.

Modern pentathlon
As the pentathlon combines target shooting, fencing, swimming, equestrian show-jumping and cross-country running events, a pool of all-round Olympic ability is needed to succeed.

Table tennis
Fast-twitch muscle fibres and lightning reactions are a must, but the best players instinctively know where to plant their feet and have the endurance to last for several hours of intense play.

Cycling (road)
Cardiovascular endurance and strong legs are a given, but arguably Lance Armstrong's heroic (and victorious) fight against cancer contributed to him winning the Tour de France no less than seven times.

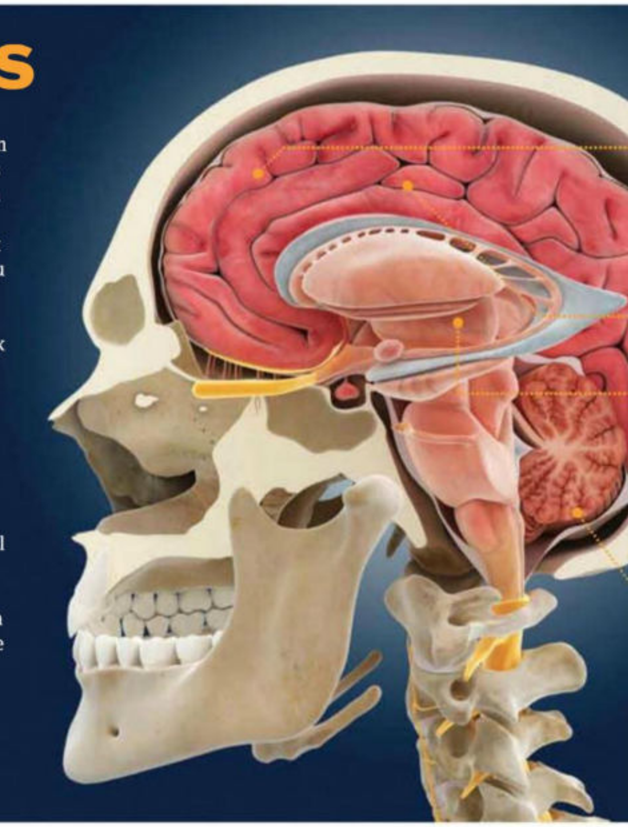
It seems unfair but genetically many, if not most, of us aren't even on an even keel with Olympians when we're born, as many athletes have a natural leaning towards superhuman traits. Long limbs, a large pool (up to 90 per cent) of slow-twitch muscle fibres and a cardiovascular system with a huge range means Kenyans tend to dominate distance events over 5,000 metres (16,400 feet). Even outside of racial predispositions, and regardless of the best training techniques, some people are just genetically overqualified for a certain sport and will leave their fellow competitors for dust.

The Olympic Games themselves have also been a catalyst for Herculean achievements. Before the first modern Olympic Games under the International Olympic Committee in 1896, the first official world record for the 100-metre (328-foot) sprint (ratified by the International Association for Athletics Federations) was 10.8 seconds, by Luther Cary in 1891. The benchmark ten-second barrier wasn't broken until 1968 and Usain Bolt smashed his own world record in Berlin three years ago with a blistering 9.58-second run. While over a century of socioeconomic improvements have helped open the Olympic achievements up to everyone, the Games themselves have provided a competitive platform from which Olympic athletes have been able to further distinguish themselves from the everyday man, proving they're capable of superhuman things.

Mind Games

While most Olympic superhumans may not necessarily directly train their minds to enable them to perform at their peak, their brains will develop as a part of their training. Marksmen of the pentathlon and champion archers can't rely on 20-20 vision alone, for example. The hand-eye co-ordination that makes the perfect shot is quite methodical when you boil it down. It begins with the brain setting the bullseye as the goal, calculating the best way to achieve it and then predicting what kind of feedback sensation it should receive if the goal is achieved.

It rapidly adjusts the Olympian's form and compensates for what it thinks is the tiniest deviation from the right technique. All our brains do this even for the simplest of activities, but superhuman brains find more efficient, more accurate ways of doing the same task. The other critical factor in any Olympian's mind is their mental readiness for action. Being calm and focused is conducive to any activity and athlete brains emit stronger alpha waves than average, which indicate a state of calm. This is because the athlete has become efficient enough to free the prefrontal cortex in the front of the brain from the task at hand, giving it space to react. The anatomy of their brain has been changed, strengthening neuron connections in some areas and weakening them in others, honing it for the person's particular sport.



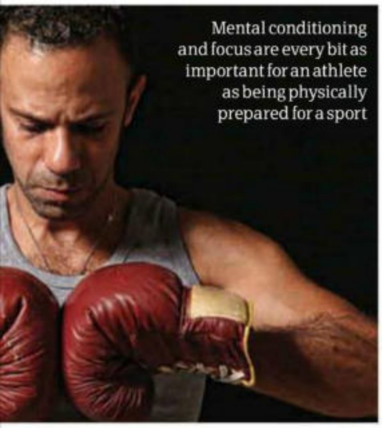
Ten seconds to gold

10 years old

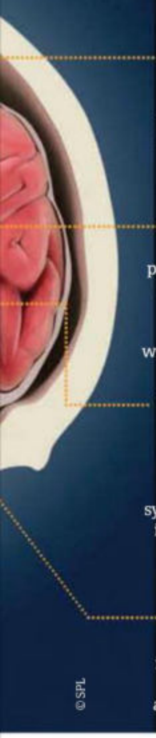
YOUNGEST-EVER OLYMPIAN

Greek gymnast Dimitrios Loundras was only ten when he competed in the 1896 Athens Olympics. The minimum age today is 14 (for diving and bobsleigh).

DID YOU KNOW? The very first recorded Olympic event (in Greece, 776 BCE) was a 192m (630ft) dash



Mental conditioning and focus are every bit as important for an athlete as being physically prepared for a sport



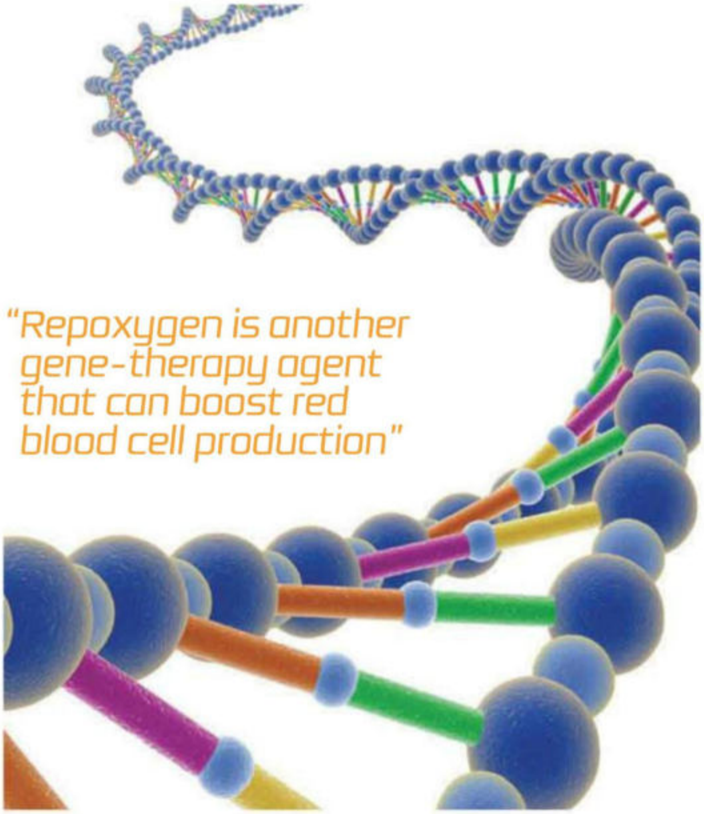
Prefrontal cortex
This is where planning and strategy take place. With practice, this can be freed up to respond more quickly and accurately.

Muscle memory
New, complex neural pathways and neurons are developed in top athletes so that they can perform sophisticated tasks without conscious thought.

Vestibular system
Though balance is also maintained by other senses and computed by the brain, the vestibular system (which is part of the inner ear) detects circular motion and movement in a straight line.

Cerebellum
Hand-eye co-ordination is computed here and can be improved, though not all cerebellums are equal.

© SPL

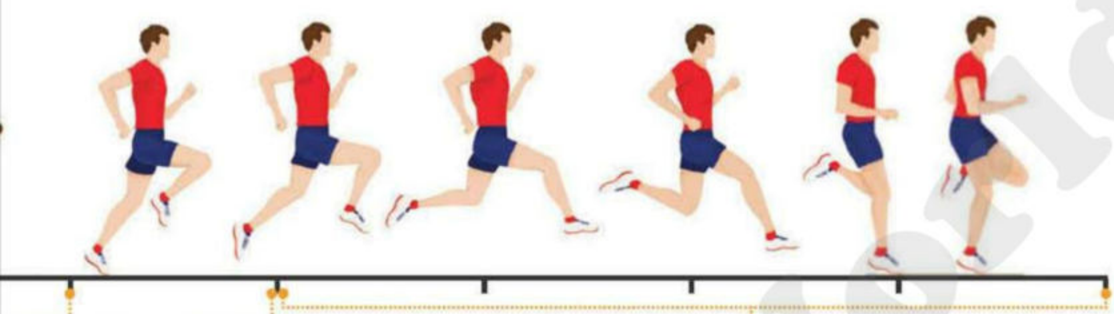


"Repoxygen is another gene-therapy agent that can boost red blood cell production"

It's all in the genes

Currently, the only way we can take charge of our own destiny and give ourselves a fighting chance of competing in the Olympic Games is by hard work and dedication – though that doesn't guarantee we'll even come close to becoming Olympic-standard. Modern technology may change that however: 'gene-doping' is the term given to a wave of genetic technologies that may allow an athlete to change their DNA in favour of becoming faster, stronger and all-round better at their event. PPAR-∂ (peroxisome proliferator-activated receptor alpha) affects muscle-cell metabolism and can potentially boost strength and power, as well as affect fat metabolism for a leaner physique. Repoxygen is another gene-therapy agent that can boost red blood cell production, increasing the amount of oxygen delivered to the muscles.

Even though either of these might put the average person on a genetic par with Olympic superheroes, using them to increase performance in professional sports is illegal, akin to using anabolic steroids and other banned substances. Currently, however, there's no way to test for such gene-altering drugs.



Lift phase
(6 seconds)

Full sprint
(6-10 seconds)

Super-human abilities

Gymnastics (artistic)
Incredible balance and flexibility aside, more than any other athlete, gymnasts require a strength-to-weight ratio that belies their slight frame.

Rowing
Again, long, strong limbs make for the longest strokes and the best rowers. Olympic rowers need to overcome lactic acid burn from anaerobic bursts that would cripple lesser men.

Boxing
Unlike most other Olympic sports, boxers are expected to endure a degree of injury to the head and body, yet continue performing at their peak. In addition to overall athletic ability, an iron jaw and a certain 'grit' are vital.

Weightlifting
Weightlifters are extreme specialists, focusing large overall muscle mass into feats of power and strength. Technique and endurance should never be underplayed, as only a flawlessly executed lift will secure full marks.

Archery
Archers need long, strong arms and back muscles, hawk-eye vision and focus to the point that the archer can temporarily lower their heart rate.

Diving
More than any other event, concentration and absolute focus are vital to a diver, because entering the water from such lofty heights with the wrong posture can be seriously dangerous.

"In the 18th and 19th centuries, heavy industry led to the process of curing steel"

In 1991, coaches of the former East German swimming team admitted to drugging their athletes, contributing to 11 gold medals in the 1976 Games

Drug testing

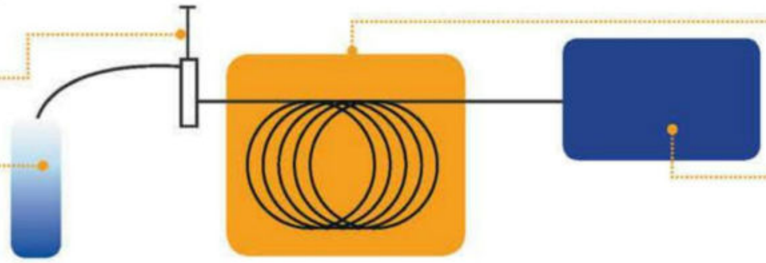
How are athletes checked for banned substances at major sporting events?

Certain drugs are banned by sporting authorities because of the unfair advantage they can give. Drugs like anabolic steroids can increase lean mass, painkillers enable athletes to endure greater stresses, sedatives can help archers focus and even chemicals to mask banned substances exist in the world of performance-enhancing drugs.

Ever since banned-substance testing began at the 1968 Olympic Games in Mexico, it's been an arms race between new drugs and the methods devised to detect them. The process for detecting a broad spectrum of forbidden substances involves a drug control officer taking a sample of an athlete's urine, or sometimes blood, for analysis at a laboratory. Here, gas chromatography and mass spectrometry (or GC-MS for short) are most commonly used to detect drugs. Gas chromatography vaporises the sample in the presence of a gas, with certain substances remaining as a gas for a specific, known amount of time.

In the final stage of the drug-testing process, mass spectrometry blasts the sample with an electron beam before sending the remains down a magnetic tube into a detector that can pick up the unique 'fingerprint' of each substance.

GC-MS in action



Sample injector
The sample taken from the athlete is injected into the oven along with the gas.

Gas
A gas, usually helium, nitrogen or hydrogen is released into a sealed oven.

Temperature-regulated oven
The gas and sample are heated and maintained at a certain temperature by a specialised oven.

Mass spectrometer
The vaporised remains of the sample and gas are passed into the mass spectrometer for analysis.

What is galvanisation?

How the strength of steel can be bolstered through the use of some clever chemistry

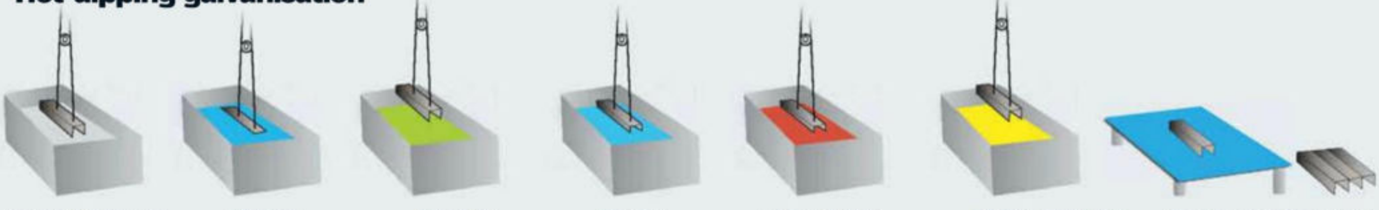
Steel has been around for millennia, ever since it was discovered that introducing carbon to the forge produced a much harder and durable metal than iron. Like iron though, it's still susceptible to the elements: exposed to moisture and oxygen in the air, it's prone to corrosion and rust. So, in the 18th and 19th centuries, heavy industry led to the process of curing steel – otherwise known as galvanising.

Hot-dipping is the most common method of galvanisation. It involves a final stage of dipping steel into a bath of molten zinc at around 460 degrees Celsius (860 degrees Fahrenheit). The zinc bonds with the steel, forming iron-zinc alloys which, in turn, forms zinc oxide on the surface. As it's the zinc that's effectively rusting and not the iron, the zinc oxide layer helps protect the steel, increasing its life span from around five years to anything up to 70 years.

Galvanised steel lasts longer today because pollution laws have helped reduce corrosive emissions in the air

© British Metal Treatments Ltd

Hot-dipping galvanisation



Caustic cleansing
Dirt, grease and oil is removed with a caustic alkaline solution.

Rinsing
The steel is rinsed in water to wash off the caustic solution.

Pickling
The surface is refined further with acid 'pickling', to remove rust and scale.

Rinsing
Another rinse to remove the acid.

Flux solution
A dip in zinc ammonium chloride removes oxides and prevents oxidation prior to the next step.

Molten zinc bath
The steel's final dip is in a bath of molten zinc at 435-455°C (815-850°F).

Cooling and cleansing
The galvanised steel is then left to cool and any excess zinc drains away.


Sea salt farmers in Pak Thale, Thailand
© JJ Harrison (www.noodlesnacks.com)

How sea salt is farmed

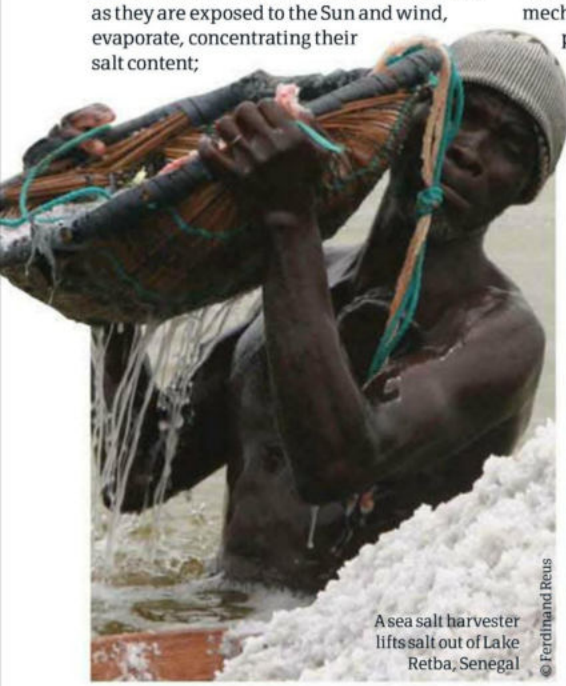
How is this popular additive extracted from the ocean to be used in kitchens all over the globe?

Sea salt is harvested in one of three ways. The first is a freeform natural technique where human labourers manually dredge natural, high salt-content waters (such as those found in Lake Retba, Senegal) with sieves. This is the oldest practice and delivers small amounts of sea salt over a long period of time – ie the supply and generation speed is controlled by entirely natural means.

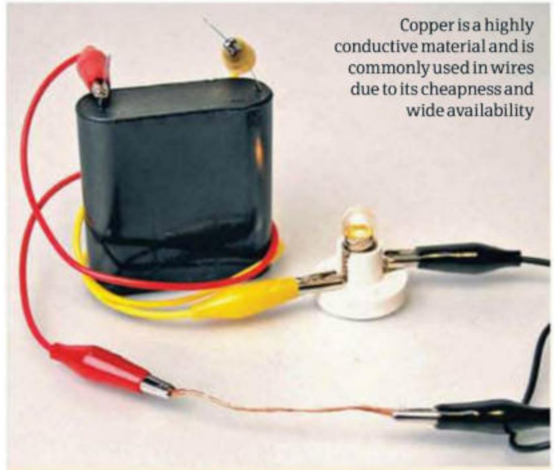
The second method is a semi-manual technique in which natural seawater resources are artificially dammed off and segmented into a series of shallow ponds (as demonstrated in the Dead Sea). These ponds, as they are exposed to the Sun and wind, evaporate, concentrating their salt content; indeed, salinity is increased almost tenfold, from around three per cent up to nearly 30. At this stage, the contained salt starts to crystallise and can be harvested manually.

The third process is an evolution of the second, with the entire operation scaled up and detached from a natural source of seawater. Here, salt water is artificially pumped into man-made shallow ponds, which are all interconnected. As the water begins to evaporate, it is moved closer and closer to a processing facility through their connections, meaning that the water in the nearest pond has the most crystallised salt. The mineral is then raked up by huge mechanical harvesters and transported to a processing facility for cleaning.

Sea salt is processed by first washing it in a brine solution in order to flush out any calcium and other impurities, and then in fresh water to dissolve any remaining magnesium chloride. After this, it can be re-dried, packaged up and distributed to retailers.


A sea salt harvester lifts salt out of Lake Retba, Senegal
© Ferdinand Reus


A view of salt evaporation pans in the Dead Sea


Copper is a highly conductive material and is commonly used in wires due to its cheapness and wide availability

Electrical conductivity explained

Why is it that some materials fight the flow of electricity while others embrace it?

Electrical conductivity is defined as a measure of how readily a material allows an electric current to pass through it. This is in contrast to electrical resistivity, which is a measure of how strongly a material opposes the flow of an electric current.

The precise conductivity level of a material is found by determining its magnitude of current density by the magnitude of its electric field. Simply put, this means that a material that can pull a large amount of current through it – even with an intrinsically small electric field – is a good conductor due to its low resistivity to electron flow.

Electron flow is characterised in a metal by the dissociation of its atoms' outer electrons from its structural lattice. These free electrons, when an electrical potential difference (ie voltage) is applied, proceed to travel from one end of a material to the other under the influence of its internal electric field. The ability and quantity of these electrons to flow uninterrupted – something that can be hampered by irregular lattices and the thermal motion of ions – dictates how much current can be effectively carried through a material. If either of these factors is excessive, then the free electrons will scatter easily from their path through the material, reducing the amount of current that can pass through, which makes for a higher resistance.

Examples of good electrical conductors include copper, gold and silver – the latter being the most electrically conductive of all metals. However, don't be fooled into thinking that non-metallic materials are not capable of conducting electricity, as plasma, salt solutions and even the carbon-based graphite all can boast high conductivity levels.

5 TOP FACTS
BAKING TRIVIA

Start with a rest
1 Giving pastry dough a chance to rest allows time for the moisture to distribute evenly through the flour, migrating from areas that are too wet to areas that aren't wet enough.

Jaffa: cake or biscuit?
2 It's an orange-flavoured cake mix in the shape of a biscuit. A 1991 legal case against McVitie's established that Jaffa Cakes are indeed cakes. This means they don't attract VAT in the UK.

Curdled eggs
3 When egg mixtures are heated too fast, the protein can become overcoagulated and separate from the liquid leaving a mixture resembling fine curds and whey.

Is it ready yet?
4 A cake is ready to be taken out of the oven when it is golden-brown and starting to come away from the edge of the tin. It should also be slightly springy to the touch.

The secret to fluffiness
5 When fat and sugar are mixed together little bubbles of air are trapped in the mixture, each one surrounded by a film of fat. It is this air which produces the lightness of the finished cake.

DID YOU KNOW? Self-raising flour contains baking powder; this ensures that the baked product will rise in the oven

The science of baking a cake

Discover the chemistry behind making the popular Victoria Sponge

Baking involves an abundance of chemical interactions. From air bubbles in the mix which expand and make the cake rise, to the stretchy gluten. Learn how all the science comes together to produce a tasty treat here…

1 MIX SUGAR, FLOUR AND BUTTER/MARGARINE

Sugar is added for sweetness while butter or margarine is added for moisture. Sugar and fat interact to create air bubbles which help make the cake fluffy. Refined white flour is usually used in cake mixture, because it is light and creates a better texture. The sugar melts into the flour at 186 degrees Celsius (367 degrees Fahrenheit), when in the oven.

2 BREAK THE EGGS

When the cake mixture is beaten, air bubbles are trapped and they help to make the cake light and airy. Eggs are critical at this point because unless beaten egg is added, the fat in the mix collapses and the air escapes during cooking. The egg white creates a film around the air bubbles, and as the cake rises during baking, the film forms a rigid wall which fixes the shape of the cake.

3 ADD BAKING POWDER

Baking powder contains sodium bicarbonate, the acidifying agent cream of tartar, and a drying agent (usually starch). When sodium bicarbonate is combined with moisture and an acidic ingredient, it produces a chemical reaction so bubbles of carbon dioxide are created. The reaction starts as soon as you mix the ingredients, so you need to bake cakes containing bicarbonate of soda immediately.

4 MIX EVERYTHING TO A GLOOPY CONSISTENCY

As you stir the mixture, the ingredients start to interact. The fat and sugar mix to create bubbles, and the baking powder is activated by the moisture from the butter/egg, releasing gas to make the dough rise. The egg binds it all together and starts to form a film around the air bubbles, while the spread ensures the cake remains moist.

5 COOK IT

Spoon the cake mixture into a tin and place in the oven. The combination of hot air trapped within the mixture, egg white protecting the air bubbles, and baking powder releasing carbon dioxide into the mix causes the cake to rise. Don't open the oven door too early because if you let cool air in before the egg has fixed the shape, then it will stop expanding and contract. As a result, the cake will collapse!

Butter/margarine
Combined with sugar, the spread forms a sweet, bubble-filled base mix, to which flour adds body.

Baking powder
Sodium bicarbonate is the key ingredient that makes cake dough rise.

Eggs
Beating in the eggs ensures that the cake mix retains its light, fluffy consistency, until baking sets the mixture.

How to make different types of pastry

Various types of pastry have slightly different ingredients and preparation methods. To make short pastry, for instance, you should mix the fat and flour, add water, roll the paste and cook at 180 degrees Celsius (356 degrees Fahrenheit).

To make puff pastry, meanwhile, the dough is layered with butter to form many layers of fat and dough. During baking, the water in the dough turns into steam and rises, creating lots of flaky layers. Flaky pastry is made in the same way, but unlike puff pastry doesn't require lots of rolling and folding.

Other leaved pastries are made from a paper-thin sheet of dough. Roll, stretch or press to create these sheets. Before placing them in the oven, you must brush with butter or oil.

How does the liver detoxify?

Optimal performance of the liver is integral to preventing disease

Toxins enter the body in food, water, through the skin and by inhalation. These toxins – such as pesticides, pharmaceutical drugs, chemicals and water-borne pollutants – end up in our bloodstream, and our liver filters the blood to remove them. Toxins are also created by biochemical reactions in the body. Toxins affect us in many ways, from drunkenness caused by alcohol to the side-effects of certain medication.

The liver transforms fat-soluble toxins into a water-soluble form. This enables them to be released through the kidneys for elimination in urine, or into bile for elimination through the colon. Enzymes chemically break down toxins which have been absorbed through the intestines. The toxins are either neutralised, or converted into a more chemically active form which is then neutralised, to be safely excreted.

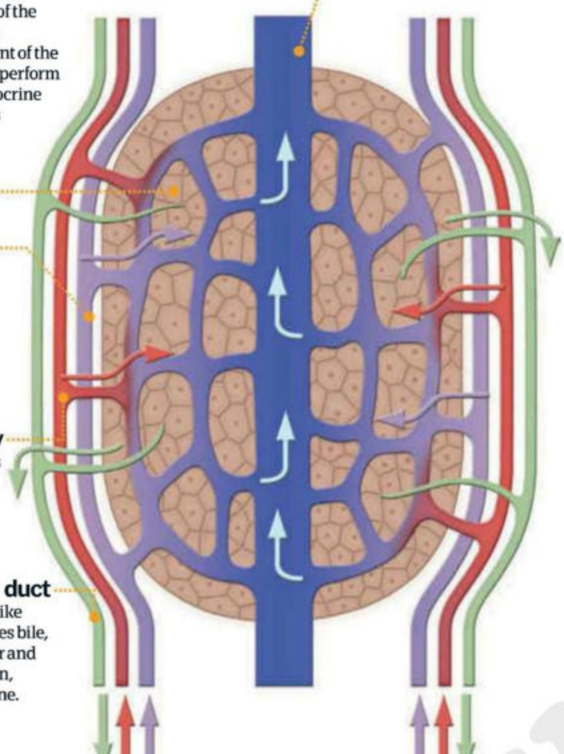
A healthy liver will manufacture approximately one litre (1.75 pints) of bile per day to transport toxins out of the body. If the liver is sluggish, toxins can build up, causing inflammation and oxidative stress. Toxins which are not eliminated return to the bloodstream and are eventually stored in fatty tissues where they pose less of an immediate threat. In the longer term, however, the slow release of these toxins back into the bloodstream can lead to a number of diseases.

Toxins come in many shapes and sizes and must all be processed by the liver for excretion

A LIVER LOBULE CLOSE UP

Central vein
The central vein receives blood from the sinusoids and returns it to circulation via the hepatic vein.

Hepatocytes
Hepatocytes are the predominant cells of the liver, making up an estimated 80 per cent of the organ's mass. They perform metabolic and endocrine functions as well as detoxification.



Branch of portal vein
This vein delivers nutrient-rich blood for use by the hepatocytes.

Branch of hepatic artery
This artery delivers oxygen-rich blood for use by the hepatocytes.

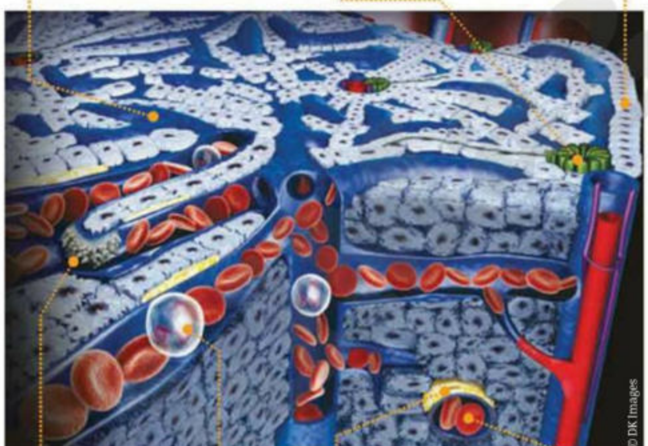
Branch of bile duct
This is a long tube-like structure that carries bile, secreted by the liver and needed for digestion, towards the intestine.

The liver at work

Sinusoid
This blood vessel carries nutrients and oxygen from the portal and hepatic arteries past the hepatocytes and back to the central vein.

Bile duct
Bile is largely produced by breaking down cholesterol, bile salts, water and bilirubin – which is a product of red blood cells.

Hepatocyte
Hepatocytes manufacture bile and secrete it into small channels which drain into the bile ducts.



© DK Images

Kupffer cell
Kupffer cells partly line the sinusoids and destroy microbes and dead cells.

White blood cell
These cells are part of the immune system and help our bodies fight off infection.

Fat-storing cell
These cells contain fat which regulates local blood flow to the hepatocytes. They play a key role in repairing cells in the liver when they're damaged.

Red blood cell
These cells carry oxygen to the body's tissues. They contain iron-rich haemoglobin, which is the pigment that makes blood red.

Welcome to...
TRANSPORT

Cars have become such everyday objects, it can be easy to forget how dangerous they are. Fortunately for us, specialist engineers – using a host of modern tech – are putting vehicles through their paces to keep us safe. Also learn about the powerful off-road EXR S, the record-breaking Lynx helicopter, plus Europe's highest elevator.

48 Westland Lynx

50 Bowler EXR S

52 Turbochargers

LEARN MORE

CRASH TESTING

How It Works visits a working crash-test centre in Germany to take a look behind the scenes at the extreme measures taken to ensure car safety

The Ford B-Max is expected to score highly on the Euro NCAP and so become one of the safest cars on the market

At the turn of the 20th century, and with the rising popularity of the automobile, the internal combustion engine pulled itself into a position of dominance over steam and electric. By the Fifties cars were a common sight – and so were car-related accidents.

Though crash testing had begun with General Motors' 1934 barrier test, car safety features of the time, such as padded dashboards and recessed controls, were considered a luxury. For owners of popular Fifties models like the 1959 Chevrolet Bel Air, you could expect a stylish set of wheels that looked like nothing else on the road. Woe betide anyone who had an accident in it though: with no seatbelts or other safety features, all occupants were left at the mercy of fate. For most car manufacturers, safety took the proverbial back seat, so crumple zones and other energy-absorbing features mandatory in the design of today's cars simply didn't exist. A 64-kilometre (40-mile)-per-hour, head-on collision would often see the Bel Air's body crumple, the driver-side door fly open and the steering column punch into the driver as the front end concertinaed.

As a result of the increasing number of cars on the road, the last half-century has seen car safety take a higher priority in the automobile industry. It's primarily been driven by legislative measures to decrease road traffic collision fatalities, rather than particular demand by consumers. Because history has shown that although we are becoming more safety conscious, we tend to buy fast, powerful, stylish, cheap and practical before safe. After all, we're planning on using our cars to take us to work, pick the kids up from school or go for day trips, and ploughing into another vehicle doesn't really factor in to our itinerary.

NCAP (the New Car Assessment Program) and Euro NCAP are the government-backed car safety evaluation schemes for the US and Europe, respectively. The Ford test centre in Merkenich, Germany, includes a 100-metre (329-foot) runway along which a sled on wheels, representing an oncoming vehicle, is propelled into the test car and then photographed with a high-speed camera at 1,000 frames per

5 TOP FACTS
SAFEST CARS

Ford C-Max

1 Though it flagged slightly in the area of pedestrian safety, the Ford C-Max scored maximum marks in 2010, which bodes well for the upcoming B-Max NCAP test.

Renault Laguna

2 The Renault Laguna scored five out of five stars in 2001 under Euro NCAP's safety assessment system of the time. It's a landmark in car safety history as the first maximum-rated car.

Volvo 122

3 Volvo included the three-point seatbelt as standard equipment in the Volvo 122, which was produced back in 1959. With this feature, it was probably the safest car of its time.

F1 cars

4 As vehicles designed to race top speeds upwards of 320 kilometres (200 miles) per hour, modern Formula 1 cars are comprehensively tested to meet strict FIA safety regulations.

Saxon APC

5 While the Saxon Armoured Personnel Carrier would shame any other vehicle for occupancy protection, a fully armoured 10.6 tonne vehicle means its top speed is only 96km/h (60mph).

DID YOU KNOW? In the UK, a driver is only responsible for passengers wearing their seatbelts if they're under the age of 14

Sensors
The sled is equipped with a variety of impact gauges at the rear that set cameras off and start measuring the moment that contact is made.

Payload
This 950kg (2,094lb) sled, when fully loaded and travelling at 50km/h (31mph), can deliver a force equivalent to the weight of three African elephants into the test car.

Bumper
Specialised honeycombed aluminium is designed to deform with a realistic impact while providing crash data for the sensors.

Crash-test essentials

You won't get very far in your crash test without a sled. This is a standard piece of kit for most impact tests – be that side, frontal or side pole impact variants. Crash sleds for small cars can travel up to 106 kilometres (66 miles) per hour and can deliver a payload of 545-2,268 kilograms (1,200-5,000 pounds). The front end comprises a honeycombed, multi-layer, side-impact barrier that deforms on contact, with sensors on the sled itself measuring dozens of different variables. Sleds are not only more cost effective than using another car to slam into the test vehicle, but they're also easily standardised (along with all the instruments on them), which is vital to ensure accuracy and consistency.

"As a result of the increasing number of cars on the road, the last half-century has seen car safety take a higher priority"

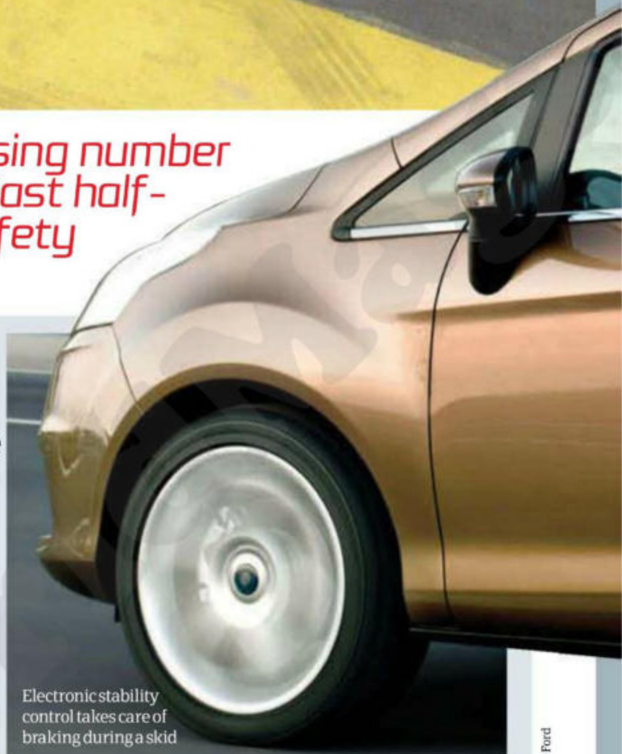
second, for experts to later examine. NCAP tests for a variety of low to medium-speed collisions, including a potentially deadly car-to-car, side-impact collision at 50 kilometres (31 miles) per hour that the new Ford B-Max – one of the safest cars in the world currently – excelled at.

Centres like this run tests on whiplash, seatbelt protection assessment and stressing the computer-controlled safety measures common in modern cars, such as electronic stability control. It's not all about the occupants either; Euro NCAP has made its pedestrian safety score an integral part of its rating. This is based on the protection a car affords to the most vulnerable areas of a pedestrian – the legs and head – on being struck at 40 kilometres (25 miles) per hour.

LETTING THE CAR TAKE CONTROL

How in-car computers keep us safe

With computers taking an ever-more prominent role in all aspects of our lives, it's not surprising that they form a significant part of many modern car safety systems too. From something as minor as an electronic voice that warns a driver when the door isn't closed properly, or if they aren't wearing their seatbelt, to far more sophisticated electronic stability control (ESC) modules that, on a fundamental level, act much the same as the stability systems aboard the Eurofighter jet. ESC works by detecting the loss of traction when a car begins to skid and applying the brakes to individual wheels to bring the car to a stop.



Electronic stability control takes care of braking during a skid

3x © Ford

"The B-Max includes an interesting active safety feature called Emergency Assist"

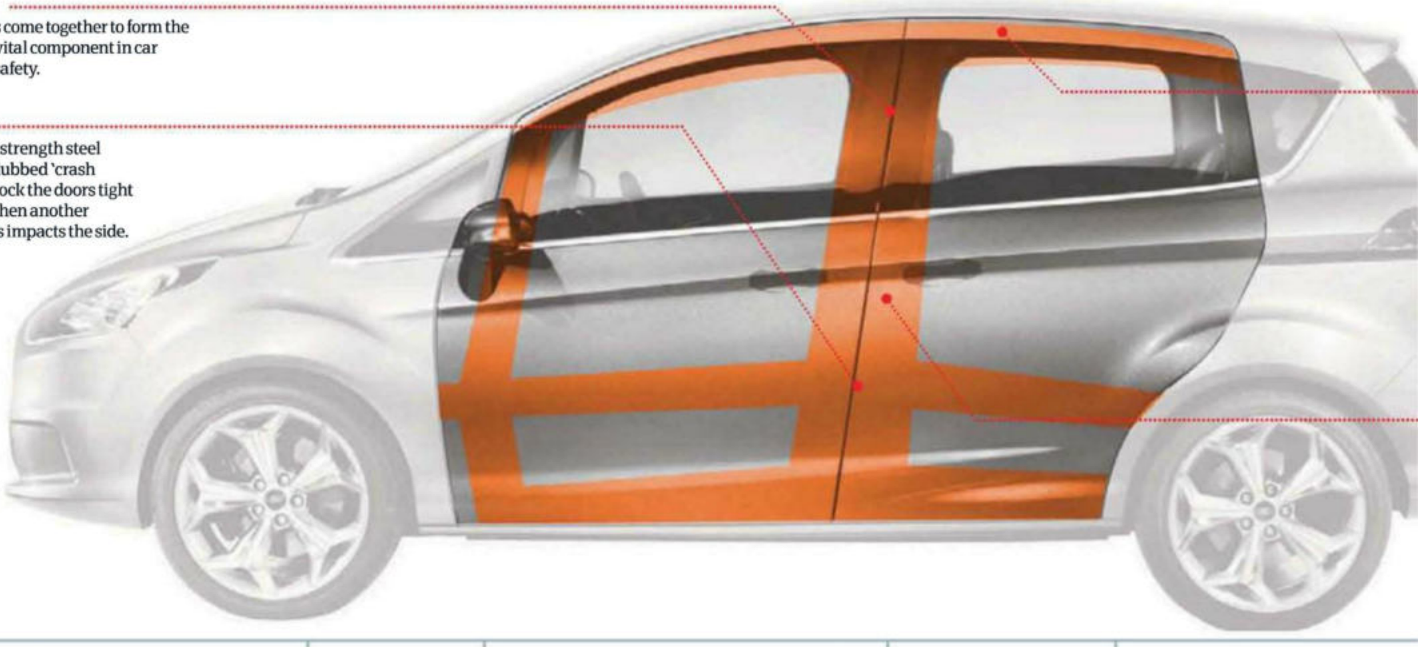
An innovative idea

Ford's aim in designing the B-Max model was to create a vehicle with no B-pillar - the central column that divides passenger and front seats - for increased accessibility. Without any support in this area however, the vehicle is structurally weak, so the B-Max incorporates reinforced doors that lock to form a B-pillar when closed

Portal
Normal doors on a vehicle with an opening like this would be catastrophic for the occupants in a high-impact collision.

B-pillar
Both doors come together to form the B-pillar, a vital component in car occupant safety.

Locks
Ultra-high strength steel brackets (dubbed 'crash catchers') lock the doors tight together when another vehicle hits impacts the side.



THE ROAD TO CAR SAFETY

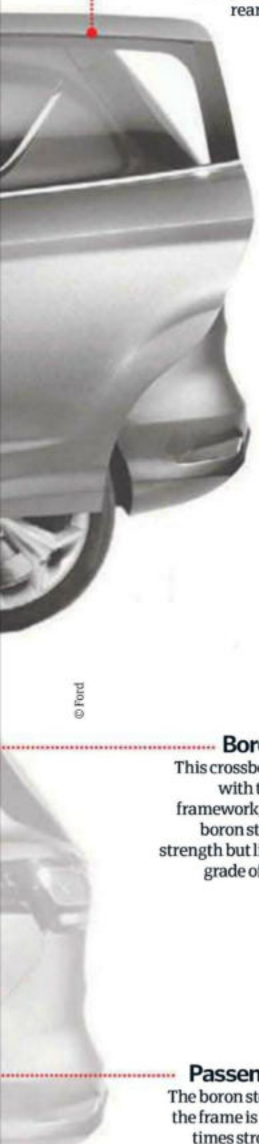
We've been driving for over a century but, until the Fifties, car safety took a back seat. But that's changed radically over the last 60 years…

1958
Volvo invents the most enduring and beneficial car safety feature ever, with Nils Bohlin patenting and refining the three-point car seatbelt.

1966
Luxury hand-built sports car Jensen FF includes the first mechanical anti-lock braking system (ABS). The system is now used as standard on most cars, including Porsche.

1979
The US National Highway Traffic Safety Administration (NHTSA) establishes the New Car Assessment Program, with the goal of encouraging automobile manufacturers to make safer cars and getting the public to buy them.

1981
German car manufacturer Mercedes becomes the first production car-maker to include a driver's airbag in its Mercedes-Benz S-Class model.



Sliding door
The rear door on the B-Max slides open only if the fuel cap, located at the rear, isn't open.

Boron steel
This crossbeam, along with the B-pillar framework, is made of boron steel, a high-strength but lightweight grade of the metal.

Passenger cell
The boron steel used in the frame is four to five times stronger than ordinary steel. It's used where impact forces are greatest in conjunction with a passenger cell designed to reduce deformation in a crash.

© Ford

HOW CAR SAFETY RATING WORKS

Take a closer look at the four main criteria on which Euro NCAP bases its safety scores

The Euro New Car Assessment Programme (Euro NCAP) scores new vehicles in four key areas: adult protection, child protection, pedestrian protection and safety assist (driver assistance and active safety technologies). The system has naturally evolved over the years with the introduction of new tech, first awarding additional points for cars incorporating them into the design, then making the new safety measures a standard part of the NCAP rating.

Adult occupant and pedestrian protection formed the original rating system when Euro NCAP was founded back in 1997, the child occupant safety rating was introduced in 2003, while safety assist only came along in 2009 with the rise of electronic safety systems. These days, new cars are tested for whiplash protection and NCAP also rewards vehicles that are installed with speed-limitation devices and electronic stability control (ESC).

Euro NCAP calculates the final rating for each vehicle by weighing up the results of these four tests, ensuring each area meets its stringent standards and then scoring out of five stars.

Emergency computer calls

The B-Max includes an interesting active safety feature called Emergency Assist. Once the system has been Bluetooth-paired with a smartphone, it places a call with a local 112 emergency operator (112 being the emergency number everywhere in the EU) if either the airbag or emergency fuel shutoff is deployed within the car.

Using the on-board GPS locator, it informs the appropriate emergency services of your location – though if it's activated by accident, there's a ten-second window in which the occupants of the B-Max can cancel the call. Emergency Assist is potentially life-saving technology and, as a result, it's looked on favourably by Euro NCAP testers.

1983
Wearing front seatbelts becomes law in the UK. A fine of up to £500 is applicable if the person responsible is convicted in court.

1997
The EC supports the Euro NCAP initiative and, in 1997, Euro NCAP releases its first results. Notably, the Rover 100 scores one out of a possible five stars.

2001
The Renault Laguna is the first Euro NCAP car to receive five out of five stars for occupant protection. Since then, car safety standards have risen as manufacturers strive to achieve this maximum safety rating.

2007
After several high-profile incidents involving pedestrians seriously hurt by 4x4 vehicles with front-mounted metal bull bars, fitting bull bars to a road vehicle becomes illegal in the UK.

2008
In response to the ever-increasing number of whiplash injury claims, Euro NCAP introduces a new whiplash prevention test.

2009
With pedestrian safety being neglected, Euro NCAP makes sure this element of road user safety is a key part of its new safety rating system. Driver-assistance technology, like ESC, also takes a more prominent role.

"The force of the impact is equivalent to three African elephants sitting on the car"

Anatomy of a deadly collision

We get an insight into a potentially devastating side-impact at a working crash test centre

The impact
It hits the test car at a 30-degree angle. Using the basic equation force = mass x acceleration (F=ma), we can work out that the sled hits the car with a force of just over 13N (3lbf).

This is a side-impact test on Ford's latest small car design. A sled loaded with sensors and a specially adapted bumper designed to accurately re-create crash forces while recording impact is propelled down the Merkenich test centre runway (which **How It Works** visited in Germany) and into the static B-Max at 50 kilometres (31 miles) per hour. It's a significant impact that could, potentially, seriously injure the occupants of the vehicle without adequate protection. Even at these low speeds the driver is susceptible to head and neck injuries because, quite incredibly, the force of the impact is equivalent to three African elephants simultaneously sitting on the side of the vehicle!

This is a standard test that every car seeking a European NCAP (New Car Assessment Programme) rating must take. What makes this one significantly different from a typical side-impact test is the B-Max itself: it has no B-pillar (the vertical beam that separates the front and back doors) and so requires some nifty engineering to make up for the structural weaknesses this design might lend itself to otherwise. The B-pillar was removed from the B-Max in order to improve accessibility, so to compensate for the structural strength that this traditional pillar provides to the framework of the car, Ford has instead integrated it into the doors.

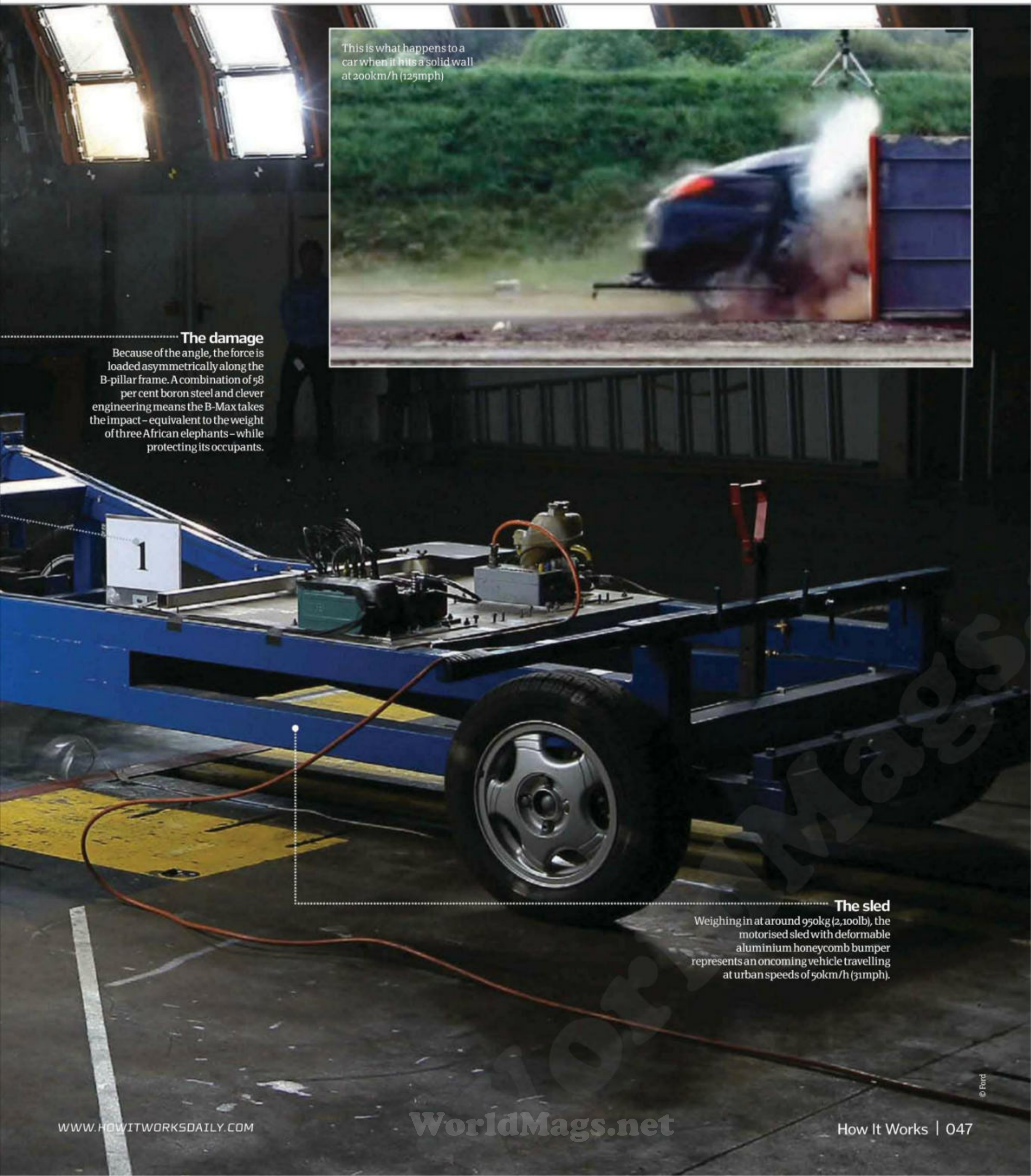
In practice – and despite the lack of rigid central column – the side-impact test result is comparable to that of a modern car with a good safety rating, as the bodywork still absorbs most of the blow. The crash-test dummies inside the B-Max were apparently rattled but, other than that, unharmed.

360MPH

FASTEST CAR CRASH SURVIVED

Donald Campbell survived crashing his car, the Bluebird, while attempting to set a new land speed record in 1960. Incredibly, he got away.

DID YOU KNOW? Even until the Fifties, some car makers insisted vehicle accidents weren't survivable due to the forces involved



This is what happens to a car when it hits a solid wall at 200km/h (125mph)

The damage
Because of the angle, the force is loaded asymmetrically along the B-pillar frame. A combination of 58 per cent boron steel and clever engineering means the B-Max takes the impact – equivalent to the weight of three African elephants – while protecting its occupants.

The sled
Weighing in at around 950kg (2,100lb), the motorised sled with deformable aluminium honeycomb bumper represents an oncoming vehicle travelling at urban speeds of 50km/h (31mph).

© Ford

"Since the first flight, over four decades ago, the Lynx has been continually upgraded and developed"

Westland Lynx

A record breaker and for 40 years – can anything beat the Lynx?

The Westland Lynx forms the backbone of the British Army and Navy helicopter forces. Entering military service in 1978, it had already set world speed records during testing. Introduced as a utility helicopter in 1971, the Lynx is a twin gas turbine-powered, two-pilot aircraft, with advanced control systems, a four-blade, semi-rigid rotor and, thanks to the fundamental stability and unrivalled agility of the basic airframe, it has performed in almost every role imaginable.

From troop transport, armed escort and anti-tank warfare with the Army Air Corps, to anti-submarine warfare and maritime attack with the Fleet Air Arm, and in many similar roles across the globe, the Lynx is used by the militaries of over a dozen countries worldwide.

This helicopter is used as an airborne command post, a fire support platform, as well as for search and rescue, casualty evacuation, plus many specialist roles including anti-pirate and border patrol. The British Army and Navy also have display teams that use the exceptional agility of the Lynx to amaze the crowds at air shows.

Since its first flight, over four decades ago, the Lynx has been continually upgraded and developed, ensuring it's always at the forefront of technology, as demonstrated by the most current variant, the Super Lynx. Army models kept the traditional landing 'skids' until only recently, when they adopted the tricycle-wheeled undercarriage used by the Navy to aid ground handling.

Improvements in navigation, communication and radar systems in Navy derivatives have ensured that British helicopter capability at sea is world leading, while Army versions have similarly demonstrated their ability to evolve with the changing requirements of modern warfare.

The latest variants are excelling on the battlefield, using state-of-the-art weapons and tactics including night-vision-assisted operations. The next generation of Lynx (the Wildcat) is currently undergoing flight testing on land and sea, ensuring many years of continued service.

Central hub
A single-piece titanium forging, the central hub takes all loads imposed by flight, as the blades rotate around it.

Engines
Two Rolls-Royce Gem 41-1 turboshafts producing 835kW (1,120shp) each spin the main rotor through a shared gearbox.

Pilots in control
The two pilots make use of the three-axes stabilisation system to gain a solid weapon launch platform.

Wheels
Unlike other Army Lynx versions, the AH.9 has a Navy-style tricycle undercarriage to help with ground handling.

Lynx AH.9 teardown

The AH.9 variant of the Lynx is used exclusively by the British Army, primarily as a utility vehicle

The statistics...

Westland Lynx AH.9

Length: 15.2m (50ft)
Rotor diameter: 12.8m (42ft)
Height: 3.8m (12.4ft)
Disc area: 128.7m² (1,385ft²)
Empty weight: 3,291kg (7,255lb)
Max takeoff weight: 5,330kg (11,750lb)
Powerplant: 2 x Rolls-Royce Gem 41-1 turboshaft, 835kW (1,120shp) each
Max speed: 324km/h (201mph)
Range: 528km (328mi)

Unbeatable record?
1 The world helicopter speed record set by G-LYNX still stands over 25 years later. With the latest fast rotorcraft moving away from eligible designs, G-LYNX's record may never be broken.

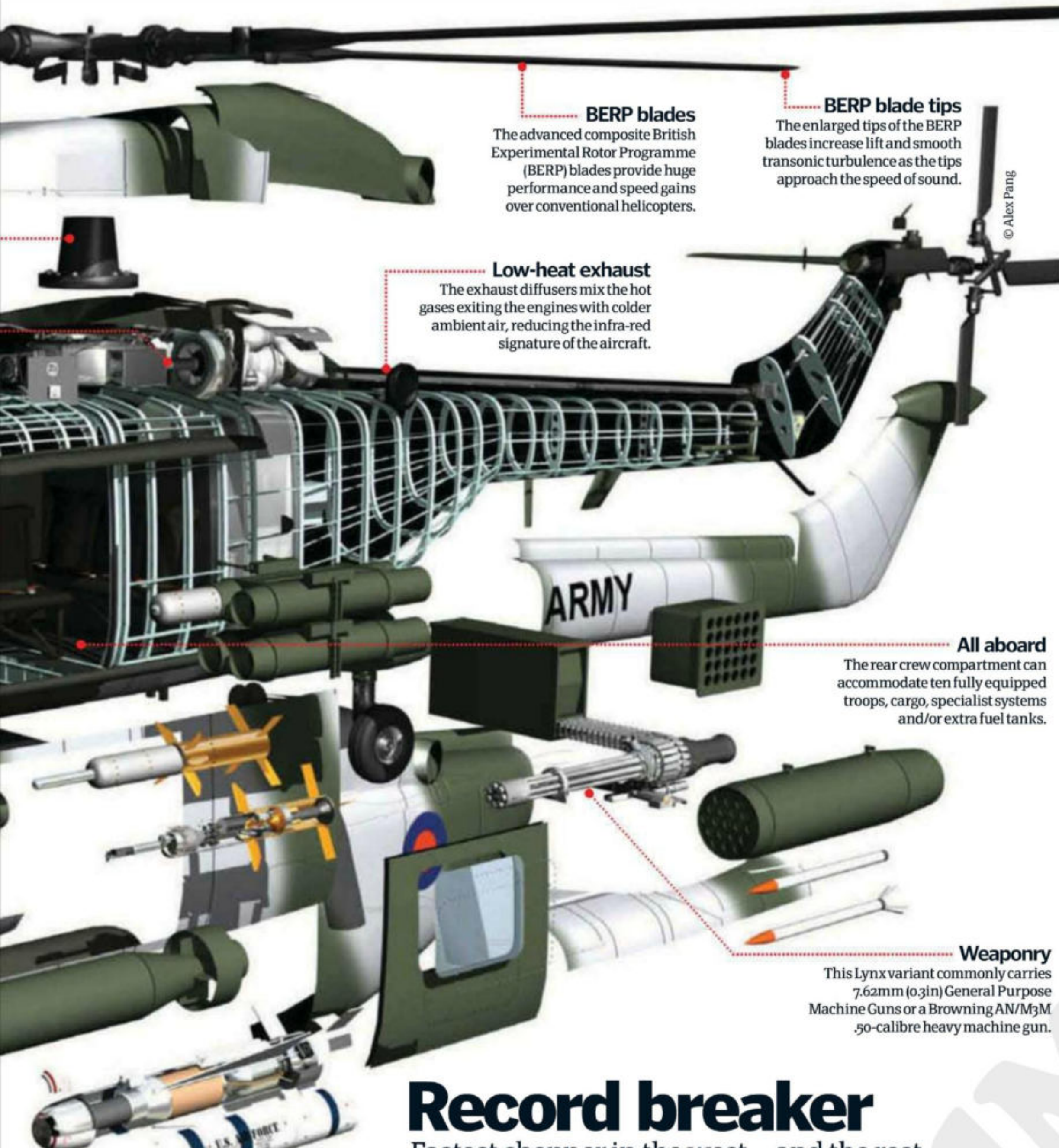
War veteran
2 The Lynx has proven capabilities in many combat environments, including disabling the Argentine submarine Santa Fe during the Falklands campaign, and sinking several Iraqi ships in the Gulf Wars.

Blow me down
3 Naval versions of the Lynx have the ability to angle the main rotor blades downwards to generate negative lift, pushing the aircraft onto the deck of a ship after landing.

More speed?
4 An even faster variant of the Lynx was proposed but never built. It would not have qualified for a world speed record, though, as it had aeroplane-like wings beneath the rotor.

Super-strong
5 The key component in the Lynx rotor is a solid titanium hub around which everything spins. This provides the strength needed for both high-speed and high-agility manoeuvres.

 The Lynx is one of the few helicopters in the world that can perform advanced aerobatics, including loops



© Alex Pang

Top trumps: MILITARY CHOPPERS

© AgustaWestland

WESTLAND LYNX AH.9

The Lynx is the smallest and lightest aircraft of the three in this roundup, which allows it to operate from small ships. The Lynx can carry more troops and is far more agile than its larger counterparts, but has less power so cannot carry as high a payload or as many weapons.

© US Navy

SIKORSKY SH-60 SEAHAWK

The Seahawk has a huge range advantage over its competitors – almost twice that of the Hind. The common parts it shares with the other aircraft in the Blackhawk family make maintenance and repair highly cost effective. However, it cannot operate from small ship decks, and is not particularly agile.

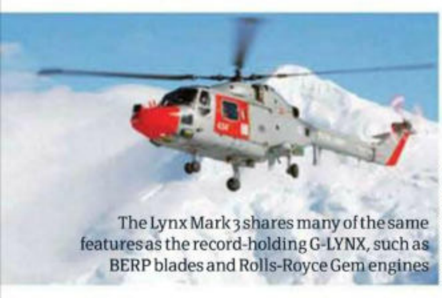
© BrokenSphere

MIL MI-24 HIND

The Hind is heavily armoured, heavily armed, extremely fast and very powerful. It is not used by the Navy due to its limited range, and its size means it is not very agile. Despite the variety of fearsome weapons that it can carry on its hardpoints, the Hind has often lacked a reliable anti-armour capability.

Record breaker

Fastest chopper in the west… and the rest



The Lynx Mark 3 shares many of the same features as the record-holding G-LYNX, such as BERP blades and Rolls-Royce Gem engines

© Crown Copyright

In 1972, just one year after its introduction, the Westland Lynx became the world's fastest helicopter when airframe XX153 set a new world speed record over 15-kilometre (9.3-mile) and 25-kilometre (15.5-mile) straight courses by flying at an average 321.7 kilometres (199.9 miles) per hour. In 1978 a heavily modified Russian Mil Mi-24 'Hind' increased this to 368.4 kilometres (228.9 miles) per hour. With Westland under political and commercial pressure, it was decided that an attempt would be made to reclaim the record. Westland re-registered Lynx airframe ZB500 as G-LYNX, and began a programme of extensive modification. More powerful Rolls-Royce Gem 60 gas turbines were fitted, along with a water-methanol injection system, but the biggest performance contribution came from the British Experimental Rotor Programme (BERP). On 8 August 1986, these advanced rotor blades carried G-LYNX pilot Trevor Egginton and his flight engineer Derek Clews to the world record speed of 400.9 kilometres (249.1 miles) per hour, which still stands to this day.

"When the Hammetschwand Lift was originally opened in 1905, it featured a wooden cabin"

© Bowler

Bowler EXR S

Put simply, the most versatile off-road car in the world

The EXR S is an advanced off-road vehicle from English company Bowler. It's an evolution of the manufacturer's existing EXR rally car, which is considered one of the most rugged off-road vehicles on Earth. The EXR S differs, however, in one key way: it performs just as well on standard public roads as it does hurtling over rocky and muddy terrain.

The EXR S's awesome off-road ability comes courtesy of its full CAD design, hydroformed base chassis, super-tough tubular steel rollcage, electronically controlled rear differential, six-speed automatic gearbox and Bilstein/Eibach suspension system. Its engine is capable of outputting a huge 620 Newton metres (457 pound-force feet) of torque over 2,200rpm. These factors, combined with colossal 56-centimetre (22-inch) wheels, mean that the car can not only tackle any extreme terrain you can think of, but can do so incredibly rapidly, hitting 0-97 kilometres (0-60 miles) per hour in just 4.2 seconds. That power and performance is not rivalled by any other off-road vehicle made to date.

The EXR S's on-road performance is the result of the powerful five-litre (1.3-gallon), V8 supercharged petrol engine, paddle-shift gear changes and Brembo disc brakes. It also boasts a host of comfort features such as climate control, a large rear load space, in-vehicle entertainment system and leather seats.

Best of the rest off-road vehicles

Jeep Wrangler
From the American off-road specialist, the Jeep Wrangler comes in two main flavours: a short-wheelbase two door and a long-wheelbase four door.


© Kobac

Range Rover
The third generation of the classic Range Rover is a larger off-road vehicle than the Wrangler and comes with either a V8 or V6 engine.

Humvee
The US military Humvee can be modified to handle many extreme environments, including having its wheels replaced with snow tracks.

Europe's highest lift explained

Find out how this impressive mountainside elevator works

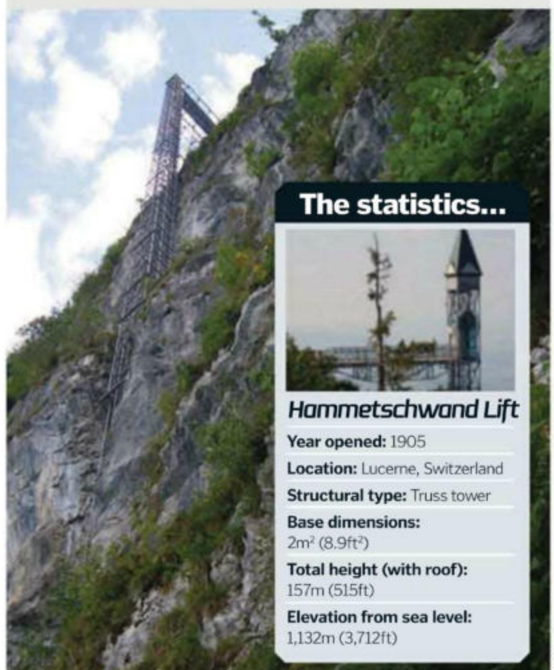
The Hammetschwand Lift in Lucerne, Switzerland, can carry its passengers to a total 1,132 metres (3,712 feet) above sea level, making it Europe's highest outdoor elevator.

The lift itself is constructed from steel and sports a filigrain, metal lattice truss tower structure, which is positioned on top of a 44-metre (144-foot) rock spit. The tower spans two square metres (6.6 square feet) at all points from the base up until the tapered roof and carries the internal aluminium and steel central cabin.

The cabin of the elevator is entered from within the Bürgenstock Mountain, which is also where its generator engine room is located, and can carry a maximum of eight passengers per trip. The cabin moves entirely vertically during its journey at a constant speed of 2.7 metres (8.9 feet) per second, a speed that enables it to make the 152-metre (499-foot) run in approximately 50 seconds.

The top of the tower is braced against the mountain plateau by a latticed steel walkway that, when the cabin has reached its highest point, allows passengers to venture out over the steep drop to enjoy the views of Lake Lucerne.

Interestingly, when the Hammetschwand Lift was originally opened in 1905, it featured a wooden cabin, which unlike its modern counterpart, could only elevate at approximately one metre (3.3 feet) per second. The refit, which took place in 1935, replaced the drive engine as well as the cab, leading it to become Europe's fastest external lift for decades, but today it can only claim to be the highest.



The statistics...

Hammetschwand Lift

Year opened: 1905

Location: Lucerne, Switzerland

Structural type: Truss tower

Base dimensions: 2m² (8.9ft²)

Total height (with roof): 157m (515ft)

Elevation from sea level: 1,132m (3,712ft)

2x © Baumanns

5 TOP FACTS: WESTLAND LYNX

Very flexible
The Lynx was the world's first fully acrobatic helicopter.

Very fast
A specially modified Lynx currently holds the helicopter speed record of 249mph.

Navy Lynx
The Navy Lynx found many export users, while the Army version found only one.

Army Lynx
While the Army Lynx can backflip and roll, the Navy version in service cannot, due to the extra weight it carries.

New Lynx's
Both the HMA.8 and the AH7 are due to be replaced by improved Lynx variants in the near future.

How it worked

Scan this QR code with your smartphone to find out more!

WESTLAND LYNX Mk.88A/HMA 8/Mk.90B

The Westland Lynx is a British multi-role helicopter that has seen service in both land-based army forms as well as ship-based naval variants. Entering service in 1977, the Lynx has since seen many upgrades and improvements throughout its service history. The Mk8 naval variant entered service with the Royal Navy in the early 1990s and has since gone on to provide them with an excellent maritime attack helicopter, performing well in the anti-submarine role as well as search and rescue and more recently anti-piracy operations off the coast of Somalia. Fiercely armed with either missiles, depth charges or a heavy machine gun the Lynx is a formidable machine and is more than capable of taking on the best of the world's surface vessels as well as any potential underwater threat.

Speed: 201 mph **Range:** 328 miles **Length:** 15.2m
Rotor diameter: 12.8m
Armament: 2 x torpedoes or 2 x depth charges or 2 x Sea Skua missiles or 1 x M3M .50cal HMG

A10107 1:48 Scale Westland Lynx Mk.88A/HMA 8/Mk.90B

"They are a 'free' performance boost and can be fitted to almost any engine"

BMW's M series of cars features a tri-turbo system, one large turbocharger with two smaller ones, a setup that offers lots of power

The cycle of a turbo

The basic principle of turbocharging is the same for all cars. Variations come in the number of turbos (some cars have two, and a recent BMW even has three) as well as the complexity of the turbo. Advanced variable vane and dual-scroll turbochargers improve response and efficiency over more basic models.

A basic priority for engine designers is to get the turbo as close to the combustion chamber as possible. This means the airflow path to the turbo is as short as it can be, maximising engine response and shortening the effect of turbo lag – the delay between pressing the accelerator pedal and the car responding.

How turbochargers boost performance

Turbochargers use waste exhaust to help cars generate more power: they really do give something for nothing…

A turbocharger is a great example of getting something from nothing. These devices use waste gases from engine combustion, normally expelled into the atmosphere through the exhaust pipe, to produce more engine power: they are essentially a 'free' performance boost and can be fitted to almost any engine.

They help make a smaller-capacity engine generate the power of a larger one, without suffering the fuel economy penalties associated with big-block engines. They also mean that smaller vehicles can have much higher outputs despite the restricted space that is afforded by their engine bays.

A turbocharger works by using the kinetic energy from the exhaust gas airflow to spin a turbine, which is connected to an air pump that compresses air via a compressor wheel. It is called forced induction, where the air is compressed in order to significantly increase its pressure, density and temperature. Alternatively, an engine without a turbocharger (an increasing rarity these days) is considered to be naturally aspirated.

Compressed, higher-density air contains more oxygen, which improves combustion and – when mixed with extra fuel – this ultimately produces more power. Each 'bang' of the engine's combustion cycle is bigger and more potent; as a result, smaller, fewer cylinders can create the same cumulative power of more and larger naturally aspirated ones.

Because a turbocharger works from waste exhaust gases, the turbine gets very hot. This heats up the compressor that, in turn, further heats up the compressed air too. Because cool air is needed for maximum efficiency, most turbocharged engines have an intercooler, through which the hot air passes and is cooled before it reaches the engine.

Today, turbochargers are used by nearly every diesel engine on the market for one very good reason: they increase the power of an inherently less efficient type of engine without negating the impressive fuel economy that many choose diesel engines for. More and more petrol cars are using turbochargers too, as car manufacturers 'downsize' their engines – replacing bigger, less green motors with smaller, more efficient engines that offer the same power.

A turbocharger's power is not quite completely free though – the additional backpressure in exhaust due to the turbine does cost a vehicle a little horsepower, but this is minimal compared to the mighty gains it brings.

Compressor air discharge
The compressor discharges air into the inlet manifold – but usually via an intercooler, to cool down the air and make it denser.

Compressor ambient air inlet
The air that the compressor acts upon comes from the atmosphere outside the car – so it is 'fresh air'.

KEY DATES
TURBO HISTORY

1885 Gottlieb Daimler and Rudolf Diesel individually attempt to turbocharge via pre-compression of the air supplied to an engine.

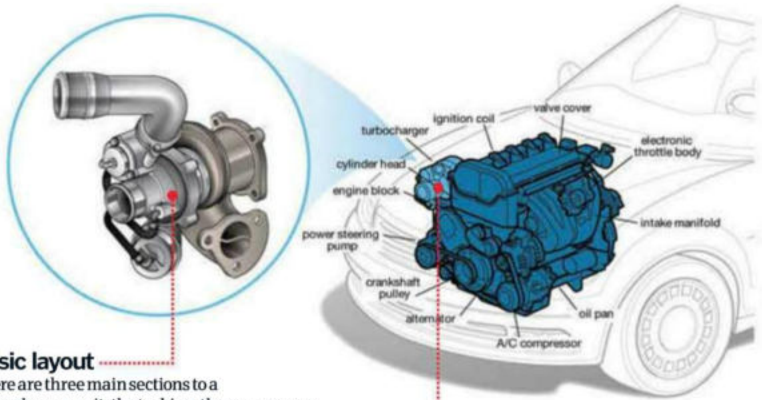
1919 General Electric completes a turbocharger for a biplane, coinciding with a new aviation height record of 8,687m (28,500ft).

1938 Swiss company Saurer brings turbocharged commercial diesel engines to the market for the first time.

1962 Chevrolet and Oldsmobile introduce the first production cars with an exhaust turbocharger.

1990 Modern turbos on many commercial vehicles are adapted to boost efficiency and lower polluting fumes.

DID YOU KNOW? A turbocharger turbine can spin at over 250,000rpm, compared to most road car engines which idle at 800rpm



Basic layout
There are three main sections to a turbocharger unit: the turbine, the compressor and the centre hub rotating assembly connecting the two separate chambers.

Turbocharger
To ensure the pressure produced by the turbo does not get too high, a wastegate regulator is usually integrated into the unit, allowing exhaust gases to bypass the turbine.

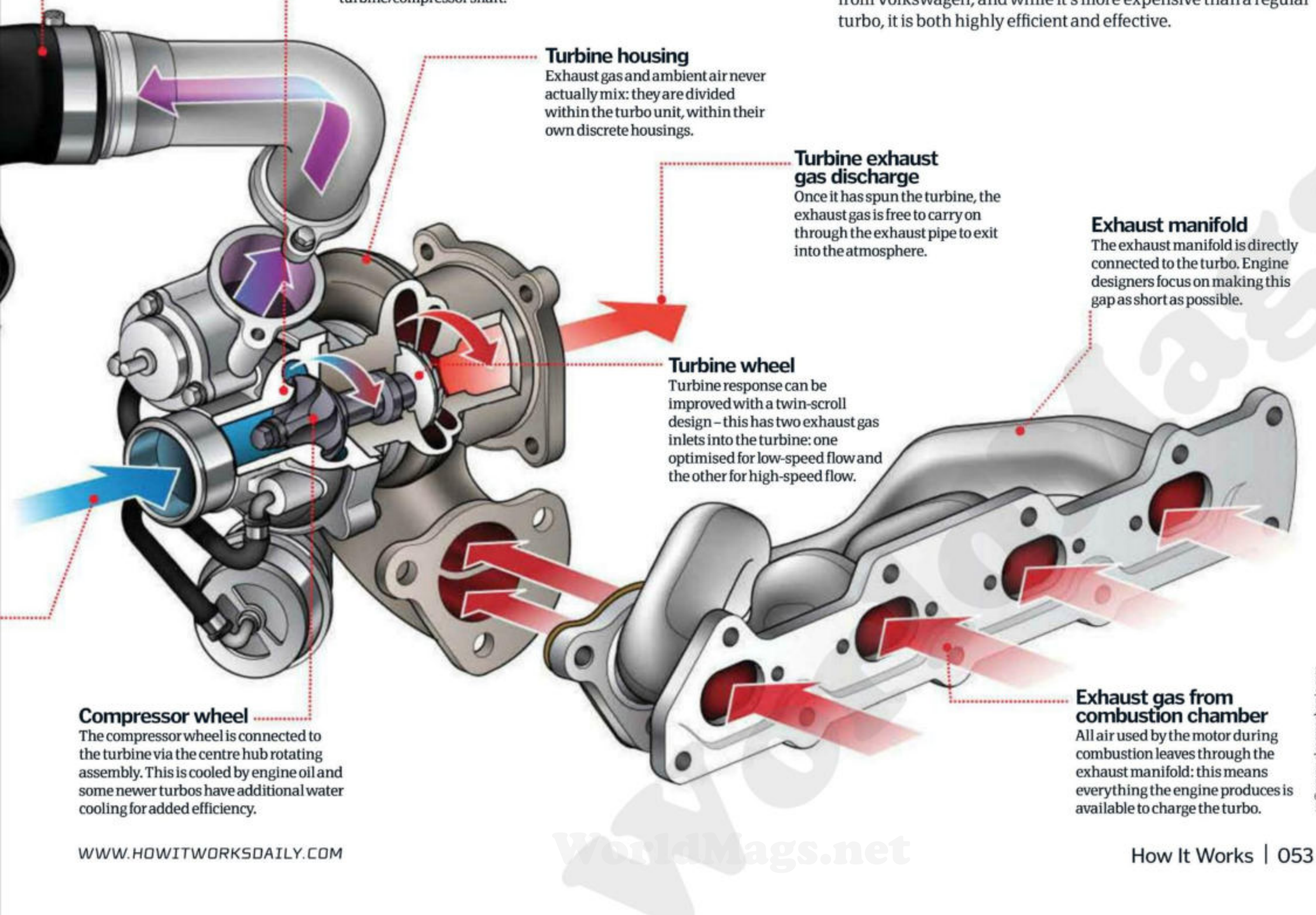
TURBOCHARGING VS SUPERCHARGING

Turbochargers and superchargers boost engine power using similar principles – ie both devices force more air into the engine for combustion, increasing the pressure in the combustion chamber and thus improving its volumetric efficiency. Nevertheless, turbocharging and supercharging work in slightly different ways to get the job done.

A supercharger is not driven 'indirectly' by exhaust gases, but is 'directly' connected to the engine, via a belt or other rigid link. A supercharger is normally driven by the crankshaft of the engine, and this direct connection means it is effective at all engine speeds, not just when exhaust gases are flowing fast enough to spin the turbine sufficiently quickly.

The major downside of superchargers is the mechanical drag that they take from the engine – with the extra friction absorbing power. For example, if a supercharger boosts an engine by 75 kilowatts (100 horsepower), 15 kilowatts (20 horsepower) of this can be taken up by actually driving the supercharger, meaning the net power gain is 60 kilowatts (80 horsepower). For this reason, turbochargers are preferable and are more fuel-efficient, despite not being quite as fast-reacting.

A twincharger engine combines both turbocharger and supercharger elements – the turbo is used at higher engine speed and the supercharger at lower speeds, when it is at its most effective and its power consumption is minimal. This 'best of both worlds' solution is used on some new car models from Volkswagen, and while it's more expensive than a regular turbo, it is both highly efficient and effective.



Turbo hose
The turbo hose is responsible for taking all charged air away from the turbo and feeding it back into the engine. This hose should be as short as possible for efficiency.

Compressor housing
A turbocharger needs very strong bearings within the compressor housing to withstand the ultra-high rotation speeds of the turbine/compressor shaft.

Turbine housing
Exhaust gas and ambient air never actually mix: they are divided within the turbo unit, within their own discrete housings.

Turbine exhaust gas discharge
Once it has spun the turbine, the exhaust gas is free to carry on through the exhaust pipe to exit into the atmosphere.

Exhaust manifold
The exhaust manifold is directly connected to the turbo. Engine designers focus on making this gap as short as possible.

Turbine wheel
Turbine response can be improved with a twin-scroll design – this has two exhaust gas inlets into the turbine: one optimised for low-speed flow and the other for high-speed flow.

Compressor wheel
The compressor wheel is connected to the turbine via the centre hub rotating assembly. This is cooled by engine oil and some newer turbos have additional water cooling for added efficiency.

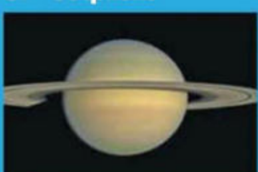
Exhaust gas from combustion chamber
All air used by the motor during combustion leaves through the exhaust manifold: this means everything the engine produces is available to charge the turbo.

Welcome to... SPACE

During a rocket launch, the vehicle itself always steals the show, but it wouldn't even get off the ground if it weren't for the technologically advanced launch pad, as we see here. Elsewhere in Space, learn about the entities gobbling up entire planets as well as the complex composition of Saturn's rings.

56 Ice volcanoes

57 Jetpacks



60 Saturn's rings

LEARN MORE

ROCKET LAUNCH PADS

The complex structures that are used to help propel rockets into space

Rotating service structure (RSS)
This provides a clean room for the servicing and installation of payloads into the shuttle's cargo bay. The whole structure swings away prior to take-off.

Fixed service structure (FSS)
The 75m (247ft)-tall launch tower has 12 floors at 6m (20ft) intervals to gain access to the shuttle.

Emergency egress system
In an emergency astronauts can escape in seven baskets that run down slidewires to a landing zone 366m (1,200ft) away at a speed of 88km/h (55mph).

Flame trench
This 12.8m (42ft)-deep, V-shaped trench underneath the MLP is covered in high temperature-resistant concrete. It deflects the heat and flames from the rocket engines and cools the MLP with water.

Launch Complex 39 ground plan
1 Vehicle assembly building (VAB)
2 Launch control centre
3 Roadway to launch pads
4 Launch Complex 39A
5 Launch Complex 39B

The launch of a rocket is the culmination of years of planning, work and expense, and the most important element in this process is the launch pad and its attendant facilities. The launch pad cradles, fuels and powers the rocket, before it is unleashed into the sky.

In the case of NASA's Space Shuttle, its rocket motors produced 3.2 million kilograms (7 million pounds) of thrust at launch. The corrosive exhaust and intense flames from the engines were channelled through a horizontal V-shaped flame trench, which consisted of two 453,600-kilogram (1 million-pound) deflectors made from steel coated with 12.7 centimetres (five inches) of heat-resistant Fondu Fyre concrete, which is sprayed with water and flakes off to disperse the intense heat.

The Space Shuttle was assembled on a moving launch platform (MLP) at the nearby vehicle assembly building (VAB) and taken to the launch pad on top of a crawler transporter. At the pad, a fixed service structure (FSS) has a lift to gain easy access to any level of the rocket. Anchored to it is the rotating service structure (RSS) that comprises a clean room used to load the rocket's cargo.

It took at least a month for 170 technicians and specialists, nicknamed 'pad rats', to prepare, check and launch the Space Shuttle, though for less complex, unmanned rockets the timescale is a matter of days. During the countdown, all links between the FSS and the rocket were systematically

LAUNCH COMPLEX 39A

Launch Complex 39A and 39B were originally built for the Apollo moon mission's Saturn V rocket. The structures on 39B have now been demolished and 39A has been mothballed

released, and lastly at blast-off explosive bolts free the shuttle from the MLP.

To protect the delicate components of the vehicle and the pad itself, the MLP is flooded with water at a rate of 3.4 million litres (900,000 gallons) per minute to suppress the damaging sound waves and heat produced by the engines.

Some support structures hold and guide the rocket, while others – like those at the Baikonur Cosmodrome in Kazakhstan – swing away from the rocket at the time of launch.

ON THE MAP

Major space centres around the globe

1 Kennedy Space Center, Merritt Island, Florida
2 Kagoshima Space Center, Kyushu, Japan
3 Xichang Space Launch Center, China
4 Baikonur Cosmodrome, Kazakhstan
5 Plesetsk Cosmodrome, Russia
6 The Guiana Space Centre, Kourou, French Guiana

Launch pad types

1 MOBILE
The German V-2 WWII rocket was carried horizontally to any available launch site on a Meillerwagen trailer. At the site, a hydraulic ram on the wagon pushed the V-2 and its support gantry into a vertical position. It was then fuelled with alcohol and liquid oxygen by tanker trucks and fired from an armoured car.

2 SEA PLATFORM
Sea Launch AG has a base in Long Beach, CA, where it assembles the rocket payload and then loads it on the Sea Launch Commander ship where it is married with the rocket. The ship transfers the rocket to the converted drilling rig Odyssey Launch Platform, which is located in the Pacific Ocean on the equator. The launch is then controlled from the Sea Launch Commander.

3 CRAWLER TRANSPORT
At the Kennedy Space Center, FL, rockets were constructed vertically in the vehicle assembly building (VAB) and taken by road on top of a specially built crawler transporter. The 40m (131ft)-long, 35m (114ft)-wide vehicle weighs 2.7 tons and, when fully loaded, has a maximum speed of just 1.6km/h (1mph).

4 RAILWAY
The Baikonur Cosmodrome, Kazakhstan, mainly uses a 470km (290mi), wide-gauge railroad network to transport its rockets to the launch site. The rockets are assembled and transported horizontally, and are erected to the vertical position at the launch pad.

5 RAMPS
The WWII V-1 flying bomb used a catapult to fire it along a short 'ski' ramp to get it in the air. Using a rail or maglev track on a mountain slope, aided by a jet or rocket booster, larger payloads could be launched with great cost and fuel savings. Today, similar systems are still being tested.

Launch emergencies

Rocket fuel is highly volatile, and when a rocket is fully fuelled and ready for launch it is like a bomb ready to explode at any moment. Problems are caused when the complex sequence of launch procedures are not followed properly, or if one or more system failures cause the rocket propellant to leak or ignite prematurely. As a rocket lifts off any loose debris or acoustic shock can severely damage the rocket and very quickly lead to a catastrophic accident.

> "It took 170 specialists, known as 'pad rats', to prepare, check and launch the Shuttle"

"WASP-12b is spilling material into its star at a rate that will see it consumed in 10 million years"


Saturn's gravitational pull creates the heat to enable icy eruptions on Enceladus

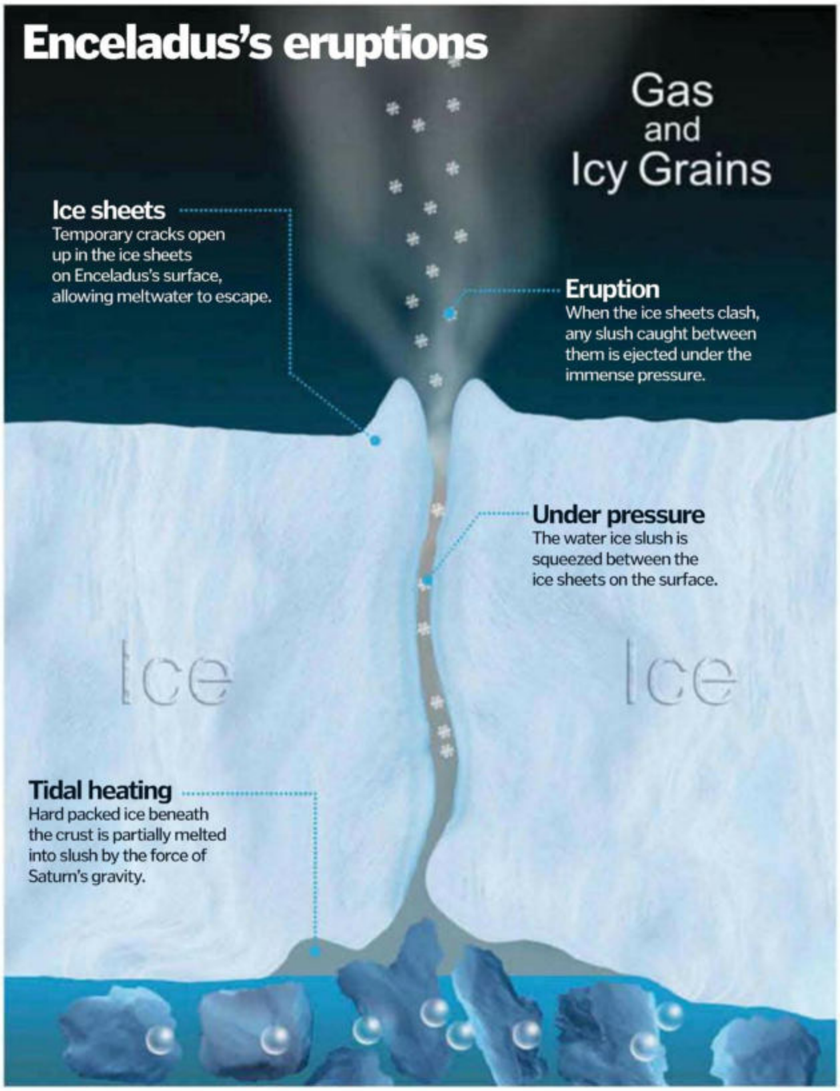
Ice volcanoes

Saturn's freezing moon Enceladus has volcanoes, but they're not what you'd expect

They're known as cryovolcanoes, and though scientists don't have cast-iron proof that volcanoes spouting ice from a sub-zero caldera exist on Enceladus, there is strong evidence for it. The flyover by Cassini two years ago revealed jets spurting from four cracks along the moon's surface, named Alexandria, Cairo, Baghdad and Damascus. The eruptions were so high that they could easily be seen in profile from space.

Volcanoes found on Earth and also Jupiter's moon Io spout silicate lava heated by the pressure beneath the crust. Ice volcanoes work in a similar way: scientists believe that subterranean geological activity on Enceladus warms the freezing surface into a slush of water, ice and organic compounds, which is then ejected by ice sheets grinding up against one another. Enceladus has an elliptical orbit similar to our moon, so as Saturn's gravity pulls unevenly at Enceladus it creates a bulge that generates the friction and heat necessary to cause this previously unheard-of phenomenon.

Enceladus's eruptions

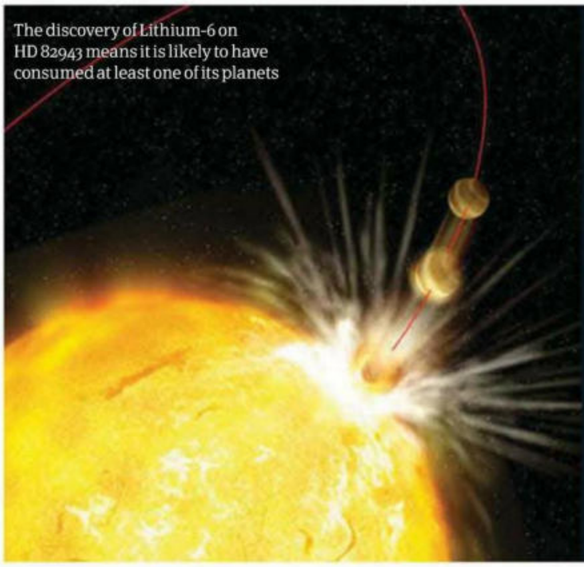


Ice sheets
Temporary cracks open up in the ice sheets on Enceladus's surface, allowing meltwater to escape.

Eruption
When the ice sheets clash, any slush caught between them is ejected under the immense pressure.

Under pressure
The water ice slush is squeezed between the ice sheets on the surface.

Tidal heating
Hard packed ice beneath the crust is partially melted into slush by the force of Saturn's gravity.


The discovery of Lithium-6 on HD 82943 means it is likely to have consumed at least one of its planets

The planet swallowers

Planets eaten by their own parent stars – it's cannibalism on a cosmic scale

Approximately 89 light years away in the constellation Hydra is the star HD 82943. It's the same temperature and size as our Sun, with a small system of its own comprising at least two gas giants orbiting it. A fairly standard cosmic entity then – except it has a dark past.

Evidence suggests HD 82943 has consumed one or more of its planets. Scientists have detected Lithium-6 on the star's surface and because this isotope is destroyed in the formation of a star, the most likely reason for it being there is because it is the remains of an orbiting planet. In another system 600 light years away, the hottest known planet in the Milky Way, WASP-12b, is so close to its parent star WASP-12 that it's being heated to 1,538 degrees Celsius (2,800 degrees Fahrenheit), causing its atmosphere to expand to three times the radius of Jupiter.

Whereas HD 82943's planets had orbits that will ultimately put them on a collision course with their star, WASP-12b is spilling material into its star at a rate that will see it utterly consumed within the next 10 million years or so.

KEY DATES
JETPACK HISTORY

1949
Rocket pack technology research begins at the Rocket Center in Redstone Arsenal, AL.

1952
Thomas Moore successfully tests a jetpack that lifts him into the air for a few seconds.

1961
Science fiction becomes reality when the military successfully showcases the jetpack to JFK.

1984
Bill Suitor flies out over the field with his jetpack in the 1984 Los Angeles Olympic Games.

1994
Mark Lee and Carl Meade give NASA's SAFER jetpack an untethered test flight.

DID YOU KNOW? *Ice volcanoes were suspected on Titan, but lack of evidence for heating under its surface has ruled them out*

An MMU enables astronauts to move untethered in space

Space mechanics

The pros and cons of anyone working in space is that you, as well as any other object, have no apparent weight. This can be great when you need to lift heavy objects around, like the 148-kilogram (326-pound) MMU, but only when you're secured to something with much greater mass than the object you're trying to shift. Newton's third law of motion states that for every action there must be an equal and opposite reaction, so the average 80-kilogram (176-pound) astronaut trying to manually push the MMU around, without standing on the Orbiter, will only succeed in pushing themselves away at a much greater velocity than they can move the MMU.

Space jetpacks

How NASA's MMU works as a jetpack in space

Space jetpacks exist, though they don't work quite as you'd see in the movies. So when, on 12 February 1984, the astronaut Bruce McCandless went free-flying 40 metres (131 feet) away from the Orbiter – farther than anyone had ever been from the safety of their ship – it was a considerable achievement. It was made possible using NASA's Manned Maneuvering Unit (MMU), a nitrogen jet-propelled backpack that is the most practical answer to science fiction's idea of a working jetpack.

Fully loaded with gaseous nitrogen propellant, the MMU weighs a hefty 148 kilograms (326 pounds). It comprises two aluminium tanks with Kevlar filament wrappings to protect them from punctures and improve strength. Each tank is loaded with 5.9 kilograms (13 pounds) of nitrogen under 20.7 kilopascals of pressure, which is enough propellant for six hours' worth of extra-vehicular activity (EVA).

Each tank feeds an individual system of thrusters through to a combination of 24 nozzles, three on each of the eight corners of the MMU. The astronaut uses their fingertips to manipulate the individual controllers, the right-hand controller rotating the MMU for roll, pitch and yaw, the left-hand controller pushing the MMU forward, back, up, down, left and right.

Once the astronaut has achieved their required position, they can subsequently engage an altitude hold function that maintains it, allowing them to work without constantly monitoring the MMU.

On one of the shuttle missions following McCandless's ground-breaking EVA flight in November 1984, astronauts Joseph Allen and Dale Gardner were able to use the revolutionary MMU to capture two rogue communication satellites which had faulty propulsion modules, then bring them back to the Orbiter to be returned to Earth.

SAFER jetpacks

More recent developments in jetpack technology have resulted in SAFER, the Simplified Aid for EVA Rescue. This is a smaller unit than the MMU and works as a safety device for use on the International Space Station (ISS). In the event of an ISS crew member working on the structure drifting away without hope of retrieval, they can use this device to return to the station.

It fits over the life support system of a spacesuit (the EMU) and has a control module and display that moves from the bottom of the SAFER to the front during operation. It has a similar build to the MMU, with gaseous nitrogen expelled from 24 nozzles that can propel the user with a similar manoeuvrability. But because it only holds 1.4 kilograms (three pounds) of propellant, it can't manage the same velocity change as the MMU.

1,930KM

BIGGEST KNOWN LANDSLIDE
An asteroid 1,930 kilometres (1,200 miles) wide caused a Martian landslide the size of the US billions of years ago, creating what's known as the Borealis Basin.

DID YOU KNOW? The farthest object NASA has found is a galaxy of blue stars some 13.2 billion light years away

Martian mudslides

Mars's barren surface isn't quite as static as we once thought…

These pictures could easily have been taken at any dusty Earth location, but they're actually snaps of Mars, taken by NASA's HiRISE (High Resolution Imaging Science Experiment) camera by mistake as scientists searched for carbon dioxide frost. The photos show four avalanches of Martian mud spilling across a strip of terrain six kilometres (3.7 miles) long and 700 metres (2,300 feet) tall, located at the Red Planet's north pole.

The landslides are actually quite small, but they've caused some excitement at NASA, partly because the planet is normally so still and lifeless that to capture these dynamic images is quite a rarity. But they have also helped to give an insight into the composition of the planet.

It's expected that the material that has fallen loose is probably more ice than red Martian dust, but by watching the debris and how rapidly it shrinks as the solids change to gas, scientists hope to apportion a precise figure over time. Also of interest to NASA scientists is the cause of the mudslide, which isn't yet clear.

These landslides on Mars have caused quite a stir at NASA

Movement like this is a rare occurrence on the Red Planet

Sizing up the universe

Can we estimate its scale – and is there any point finding out how large it is?

Up until around 100 years ago, astronomers believed our Milky Way was the entire universe

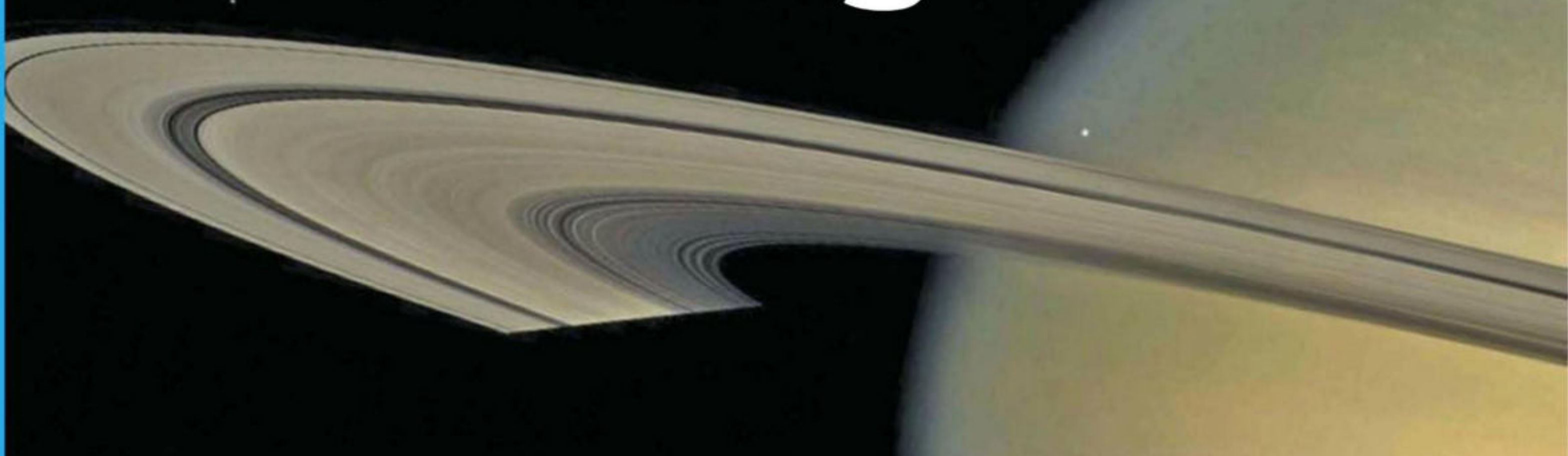
One of the greatest challenges that astronomers face is determining distances beyond the reach of current science. For instance, today, we can estimate that the universe has a radius of around 13 billion light years, a figure obtained by multiplying our estimated age of the universe by the speed of light.

The reason why this fairly basic equation is used is that we can only see as far as the distance that light could have reached us since the universe began. Scientists can get a good idea of the age of the universe by estimating the age of the oldest stars we can see, which evolve predictably over billions of years according to the conventions of atomic and nuclear physical theories. They can also estimate the time of the Big Bang by calculating the distances of many galaxies, then establishing the speed that they're moving at and extrapolating back.

Ultimately, we are limited by what we can observe, because some scientific theories propose that the universe expanded so rapidly after the Big Bang event that only part of it has remained within range of our current methods of detection.

"Its diffuse E ring is truly gigantic at around 300,000 kilometres [186,000 miles] wide"

What are Saturn's rings?



The mysteries of how Saturn's rings were formed are only now revealing themselves to us…

While both Neptune and Uranus can boast of being encircled by a stellar crown of sorts, it's Saturn that is the true 'lord of the rings'. Neptune's five relatively thin rings are so small that they weren't definitively discovered until 1968, while Uranus's narrow bands were discovered even later, in 1977. By contrast, Galileo was the first person to view Saturn's rings over 400 years ago using a simple telescope.

Six of its seven rings span from 74,500 kilometres (46,300 miles) to 140,220 kilometres (87,130 miles) above the surface of Saturn, while its diffuse E ring is truly gigantic at around 300,000 kilometres (186,000 miles) wide – nearly the distance between the Earth and the moon.

Most of the rings are primarily composed of water ice that ranges in size from tiny droplets micrometres across to large chunks the size of houses. Icy moons like Enceladus that orbit Saturn help seed the enormous E ring by spouting water slush and organic compounds from beneath its frozen crust into the atmosphere and way beyond. Rock particles of a similar size, but much greater mass than the ice particles, can also be found within the rings.

One theory is that Saturn's main rings, A, B and C – the first ones that were discovered – were actually created much earlier than had been previously thought. Rather than at the time of the formation of the solar system, space scientists think the rings may have been formed a few hundred million years ago when a large moon or asteroid was broken apart by Saturn's gravity.

Saturn's rings close up

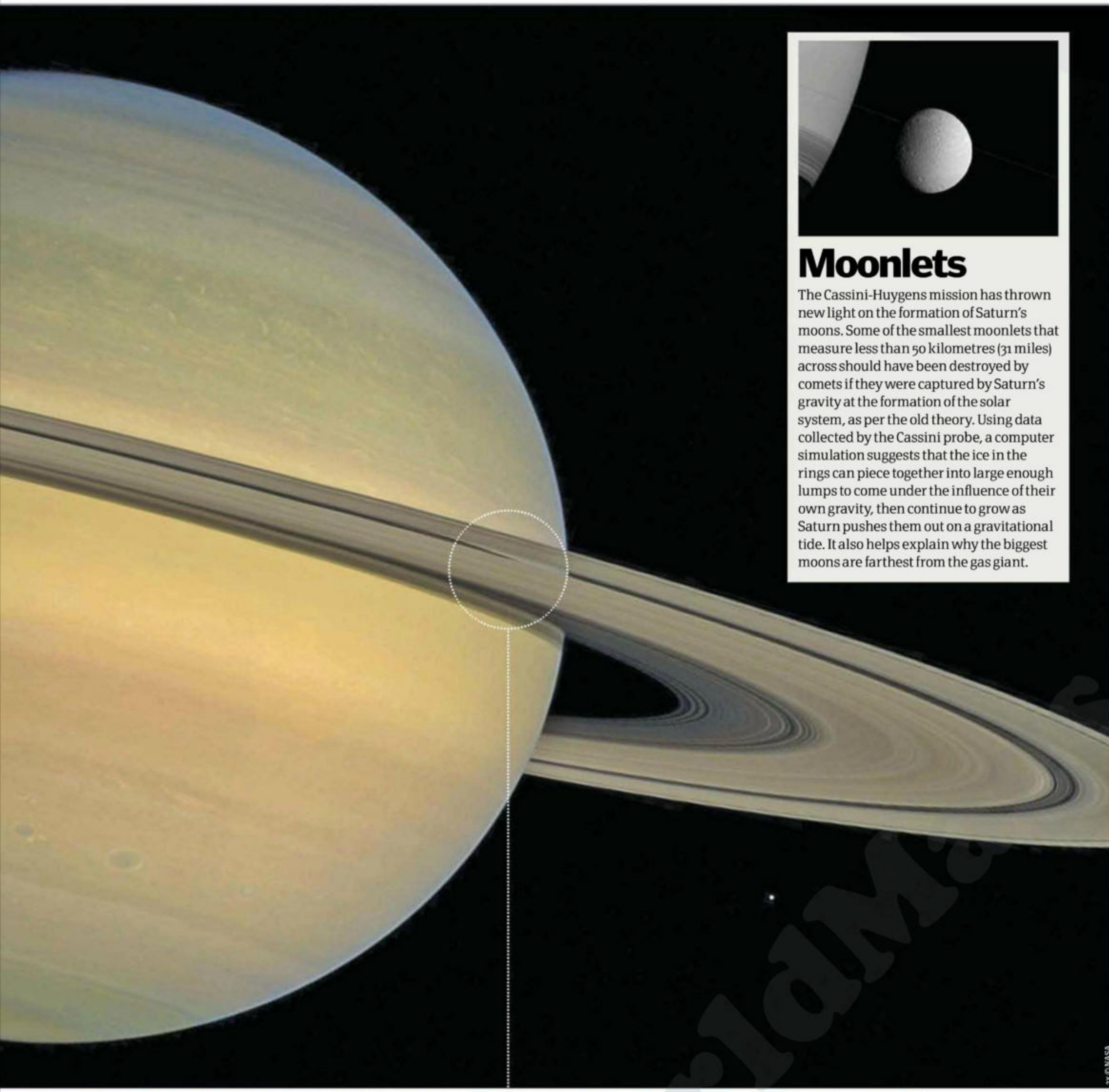
AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

NASA captures the sound of Saturn and its rings

www.howitworksdaily.com

DID YOU KNOW? Saturn's largest moon, Titan, has a diameter of 5,150 kilometres (3,200 miles)



Moonlets

The Cassini-Huygens mission has thrown new light on the formation of Saturn's moons. Some of the smallest moonlets that measure less than 50 kilometres (31 miles) across should have been destroyed by comets if they were captured by Saturn's gravity at the formation of the solar system, as per the old theory. Using data collected by the Cassini probe, a computer simulation suggests that the ice in the rings can piece together into large enough lumps to come under the influence of their own gravity, then continue to grow as Saturn pushes them out on a gravitational tide. It also helps explain why the biggest moons are farthest from the gas giant.

2x © NASA

Welcome to... ENVIRONMENT

There are very few topics more universally talked about than the weather. This issue we put together 50 fascinating tidbits about meteorological phenomena, shedding light on myths like raining fish, to the science behind storms and how, in many ways, our lives are dictated by the weather.

LEARN MORE

50 AMAZING FACTS ABOUT WEATHER

How many lightning strikes are there each second globally?
100

How high is a typical cloud?
2,000m
(6,550ft)

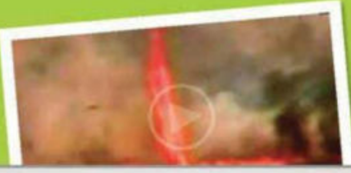
How many thunderstorms break out worldwide at any given moment?
2,000

How hot is the Sun? The core is around
15,000,000°C
(27,000,000°F)

We answer your burning questions about the incredible variety and awesome power of the planet's most intriguing climatic phenomena

We like to be able to control everything, but weather – those changes in the Earth's atmosphere that spell out rain, snow, wind, heat, cold and more – is one of those things that is just beyond our power. Maybe that's why a cloudless sunny day or a spectacular display of lightning both have the ability to delight us. Meteorologists have come a long way in their capability to predict weather patterns, track changes and forecast what we can expect to see when we leave our homes each day. But they're not always right. It's not their fault; we still don't completely understand all of the processes that contribute to changes in the weather.

Here's what we do know: all weather starts with contrasts in air temperature and moisture in the atmosphere. Seems simple, right? Not exactly. Temperature and moisture vary greatly depending on a huge number of factors, like the Earth's rotation, where you're located, the angle at which the Sun is hitting it at any given time, your elevation, and your proximity to the ocean. These all lead to changes in atmospheric pressure. The atmosphere is chaotic, meaning that a very small, local change can have a far-reaching effect on much larger weather systems. That's why it's especially tough to make accurate forecasts more than a few days in advance.



DID YOU KNOW? Many types of animals are reported to have fallen from the sky including frogs, worms and fish

Is there a way to tell how close a storm is?

Lightning and thunder always go together, because thunder is the sound that results from lightning. Lightning bolts are close to 30,000 degrees Celsius (54,000 degrees Fahrenheit), so the air in the atmosphere that they zip through becomes superheated and quickly expands. That sound of expansion is called thunder, and on average it's about 120 decibels (a chainsaw is 125, for reference). Sometimes you can see lightning but not hear the thunder, but that's only because the lightning is too far away for you to hear it. Because light travels faster than sound, you always see lightning before hearing it.

1. Start the count
When you see a flash of lightning, start counting. A stopwatch would be the most accurate way.

2. Five seconds
The rule is that for every five seconds, the storm is roughly 1.6 kilometres (one mile) away.

3. Do the maths
Stop counting after the thunder and do the maths. If the storm's close, take the necessary precautions.


Lightning occurs most often in hot, summer-like climates

Where are you most likely to get hit by lightning?

Generally lightning strikes occur most often during the summer. So the place where lightning strikes occur the most is a place where summer-like weather prevails year-round: Africa. Specifically, it's the village of Kifuka in the Democratic Republic of Congo. Each year, it gets more than 150 lightning strikes within one square kilometre. Roy Sullivan didn't live in Kifuka but he still managed to get struck by lightning seven separate times while working as a park ranger in the Shenandoah National Park in the USA. The state in which he lived – Virginia – does have a high incidence of lightning strikes per year, but since Sullivan spent his job outdoors in the mountains, his risk was greater due to his exposure.

What is the fastest wind ever recorded, not in a tornado?

407km/h (253mph) Gusts recorded during Cyclone Olivia in 1996

Is it possible to stop a hurricane?

We can't control the weather… or can we? Some scientists are trying to influence the weather through cloud seeding, or altering the clouds' processes by introducing chemicals like solid carbon dioxide (aka dry ice), calcium chloride and silver iodide. It has been used to induce rainfall during times of drought as well as to prevent storms.

CAN IT REALLY RAIN ANIMALS?

Animals have fallen from the sky before, but it's not actually 'raining' them. More likely strong winds have picked up large numbers of critters from ponds or other concentrations – perhaps from tornadoes or downspouts – then moved and deposited them. Usually the animals in question are small and live in or around water for a reason.

DOES FREAK WEATHER CONFUSE WILDLIFE?

A short period of unseasonable weather isn't confusing, but a longer one can be. For example, warm weather in winter may make plants bloom too early or animals begin mating long before spring actually rolls around.

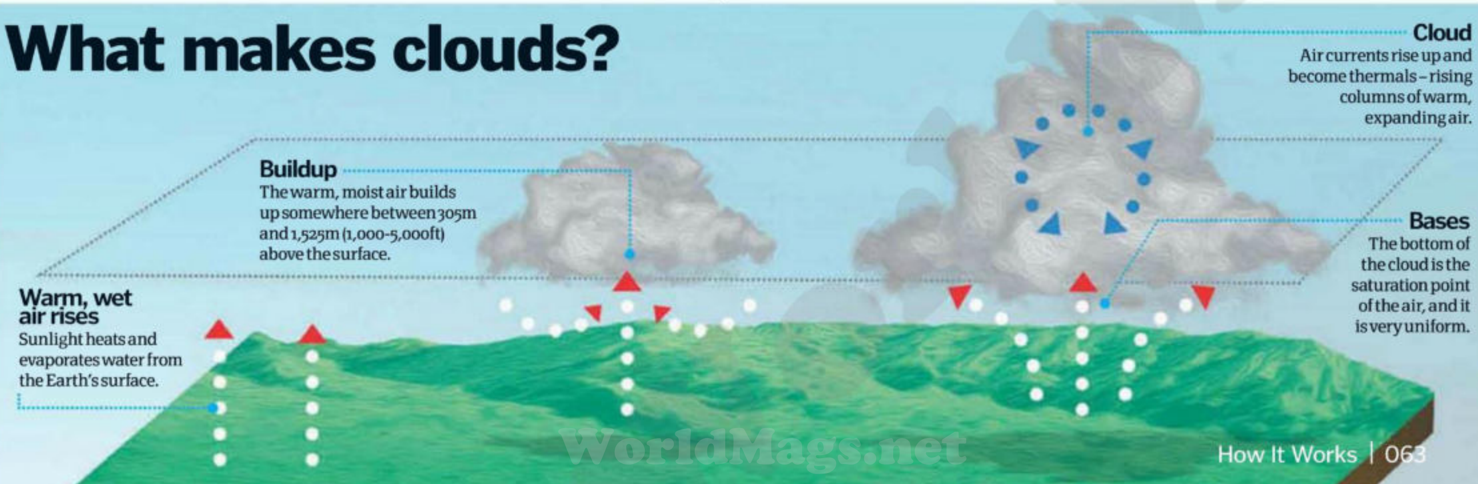
IS THE 'RED SKY AT NIGHT, SHEPHERD'S DELIGHT' SAYING TRUE?

The rest of the proverb is, 'Red sky at morning, shepherd's warning'. A red sky means you could see the red wavelength of sunlight reflecting off clouds. At sunrise, it was supposed to mean the clouds were coming towards you so rain might be on the way. If you saw these clouds at sunset, the risk had already passed. Which is 'good' or 'bad' is a matter of opinion.

WHAT ARE SNOW DOUGHNUTS?

Snow doughnuts, or rollers, are a rare natural phenomenon. If snow falls in a clump, gravity can pull it down over itself as it rolls. Normally it would collapse, but sometimes a hole forms. Wind and temperature also play key roles.

What makes clouds?



"Hurricanes may also be known as tropical cyclones or typhoons"

What are the odds of getting hit by lightning in a lifetime?

1 in 10,000

WHAT ARE KATABATIC WINDS?

From the Greek for 'going downhill', a katabatic wind is also known as a drainage wind. It carries dense air down from high elevations, such as mountain tops, down a slope thanks to gravity. This is a common occurrence in places like Antarctica's Polar Plateau, where incredibly cold air on top of the plateau sinks and flows down through the rugged landscape, picking up speed as it goes. The opposite of katabatic winds are called anabatic, which are winds that blow *up* a steep slope.

DOES IT EVER SNOW IN AFRICA?

Several countries in Africa see snow – indeed, there are ski resorts in Morocco and regular snowfall in Tunisia. Algeria and South Africa also experience snowfall on occasion. It once snowed in the Sahara, but it was gone within 30 minutes. There's even snowfall around the equator if you count the snow-topped peaks of mountains.

WHAT COLOUR IS LIGHTNING?

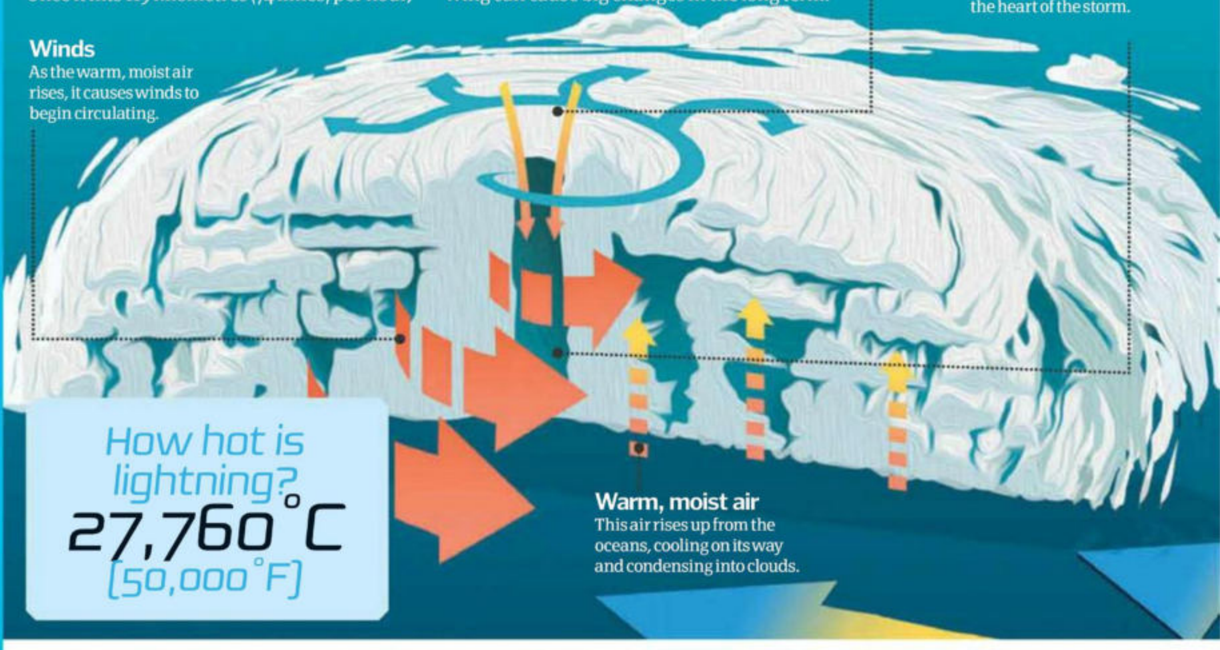
Usually lightning is white, but it can be every colour of the rainbow. There are a lot of factors that go into what shade the lightning will appear, including the amount of water vapour in the atmosphere, whether it's raining and the amount of pollution in the air. A high concentration of ozone, for example, can make lightning look blue.

WHY DO SOME CITIES HAVE THEIR OWN MICROCLIMATE?

Some large metropolises have microclimates – that is, their own small climates that differ from the local environment. Often these are due to the massive amounts of concrete, asphalt and steel; these materials retain and reflect heat and do not absorb water, which keeps a city warmer at night. This phenomenon specifically is often known as an urban heat island. The extreme energy usage in large cities may also contribute to this.

What causes hurricanes?

Depending on where they start, hurricanes may also be known as tropical cyclones or typhoons. They always form over oceans around the equator, fuelled by the warm, moist air. As that air rises and forms clouds, more warm, moist air moves into the area of lower pressure below. As the cycle continues, winds begin rotating and pick up speed. Once it hits 119 kilometres (74 miles) per hour, the storm is officially a hurricane. When hurricanes reach land, they weaken and die without the warm ocean air. Unfortunately they can move far inland, bringing a vast amount of rain and destructive winds. People sometimes cite 'the butterfly effect' in relation to hurricanes. This simply means something as small as the beat of a butterfly's wing can cause big changes in the long term.



How hot is lightning?

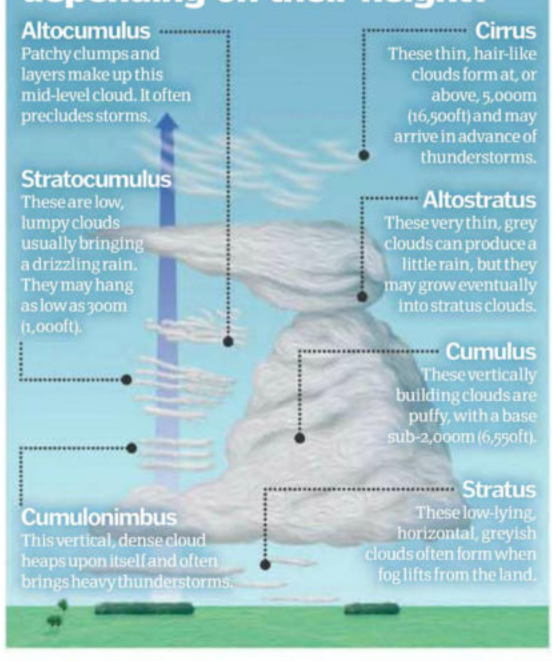
27,760°C (50,000°F)

If the moon didn't exist it would have a catastrophic effect on world climates

What would happen to our weather without the moon?

It's difficult to know exactly what would happen to our weather if the moon were destroyed, but it wouldn't be good. The moon powers Earth's tides, which in turn influence our weather systems. In addition, the loss of the moon would affect the Earth's rotation – how it spins on its axis. The presence of the moon creates a sort of drag, so its loss would probably speed up the rotation, changing the length of day and night. In addition it would alter the tilt of the Earth too, which causes the changes in our seasons. Some places would be much colder while others would become much hotter. Let's not neglect the impact of the actual destruction, either; that much debris would block out the Sun and rain down on Earth, causing massive loss of life. Huge chunks that hit the ocean could cause great tidal waves, for instance.

Why do clouds look different depending on their height?



3.7-4MN

DEADLIEST NATURAL DISASTER

The Huang He flood of 1931 covered over 100,000 square kilometres (62,000 square miles) around the Yellow River basin in China, claiming up to a staggering 4 million lives.

DID YOU KNOW? Sir Francis Beaufort devised his wind scale by using the flags and sails of his ship as measuring devices

How many volts are in a lightning flash?

1 billion

Why are you safer inside a car during an electrical storm?

People used to think the rubber tyres on a car grounded any lightning that may strike it and that's what kept you safe. However, you're safer in your car during an electrical storm because of the metal frame. It serves as a conductor of electricity, and channels the lightning away into the ground without impacting anything – or anyone – inside; this is known as a Faraday cage. While it is potentially dangerous to use a corded phone or other appliances during a storm because lightning can travel along cables, mobile or cordless phones are fine. It's also best to avoid metallic objects, including golf clubs.

© SPL

What is ball lightning?

This mysterious phenomenon looks like a glowing ball of lightning, and floats near the ground before disappearing, often leaving a sulphur smell. Despite many sightings, we're still not sure what causes it.

© SPL

What causes giant hailstones?

Put simply, giant hailstones come from giant storms – specifically a thunderstorm called a supercell. It has a strong updraft that forces wind upwards into the clouds, which keeps ice particles suspended for a long period. Within the storm are areas called growth regions; raindrops spending a long time in these are able to grow into much bigger hailstones than normal.

WHAT IS CLOUD IRIDESCENCE?

This happens when small droplets of water or ice crystals in clouds scatter light, appearing as a rainbow of colours. It's not a common phenomenon because the cloud has to be very thin, and even then the colours are often overshadowed by the Sun.

WHAT DO WEATHER SATELLITES DO?

The GOES (Geostationary Operational Environmental Satellite) system is run by the US National Environmental Satellite, Data, and Information Service (NESDIS). The major element of GOES comprises four different geosynchronous satellites (although there are other geo-satellites either with other uses now or decommissioned).

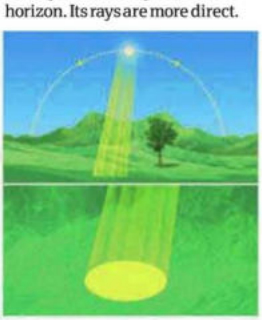
The whole system is used by NOAA's National Weather Service for forecasting, meteorological research and storm tracking. The satellites provide continuous views of Earth, giving data on air moisture, temperature and cloud cover. They also monitor solar and near-space activities like solar flares and geomagnetic storms.

How does the Sun cause the seasons?

Seasons are caused by the Earth's revolution around the Sun, as well as the tilt of the Earth on its axis. The hemisphere receiving the most direct sunlight experiences spring and summer, while the other experiences autumn and winter. During the warmer months, the Sun is higher in the sky, stays above the horizon for longer, and its rays are more direct. During the cooler half, the Sun's rays aren't as strong and it's lower in the sky. The tilt causes these dramatic differences, so while those in the northern hemisphere are wrapping up for snow, those in the southern hemisphere may be sunbathing on the beach.

SUMMER

The Sun is at its highest point in the sky and takes up more of the horizon. Its rays are more direct.

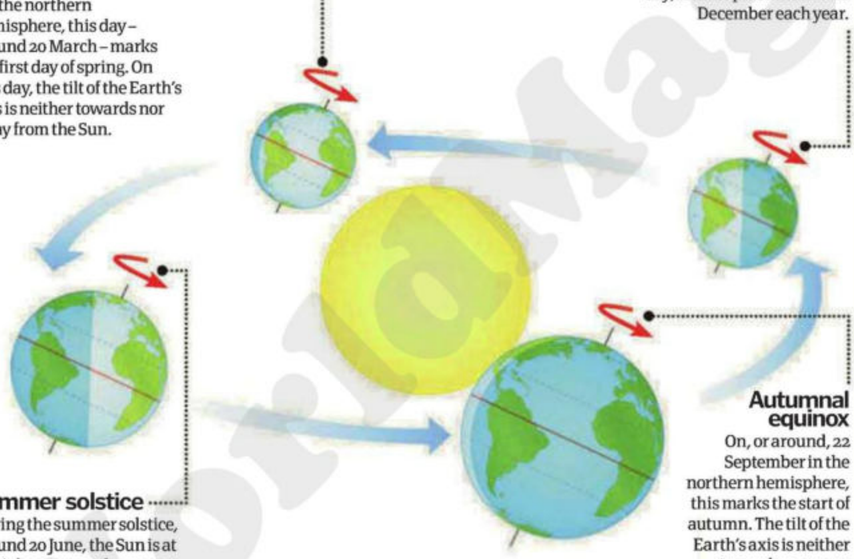


WINTER

The Sun is at its lowest point in the sky and there is less daylight. The rays are also more diffuse.

Vernal equinox
For the northern hemisphere, this day – around 20 March – marks the first day of spring. On this day, the tilt of the Earth's axis is neither towards nor away from the Sun.

Winter solstice
The winter solstice marks the beginning of winter, with the Sun at its lowest point in the sky; it takes place around 20 December each year.



Summer solstice
During the summer solstice, around 20 June, the Sun is at its highest, or northernmost, point in the sky.

Autumnal equinox
On, or around, 22 September in the northern hemisphere, this marks the start of autumn. The tilt of the Earth's axis is neither towards nor away from the Sun.

"A weather front is the separation between two different masses of air"

HOW LONG DOES A RAINBOW LAST?

There is no set rule for the duration a rainbow will last. It all depends on how long the light is refracted by water droplets in the air (eg rain, or the spray from a waterfall).

WHY DOES IT SMELL FUNNY AFTER RAIN?

This scent comes from bacteria in the soil. Once the earth dries, the bacteria (called actinomycetes) release spores. Rainfall kicks these spores up into the air, and then the moist air disperses them. They tend to have a sweet, earthy odour.

HOW MUCH RAIN CAN A HURRICANE BRING?

The average hurricane, with a radius of about 1,330 kilometres (825 miles), can dump as much as 21.3×10^{15} cubic centimetres (1.3×10^{15} cubic inches) of water a day. That's enough rain to fill up 22 million Olympic-size swimming pools!

HOW DO DROUGHTS AND HEAT WAVES DIFFER?

Droughts are about an extreme lack of water, usually due to lower than average rainfall, and last for months or even years. There's no set definition of a heat wave, but it typically means higher than average temperatures for several consecutive days. Both can lead to crop failures and fatalities.

WHY ARE RAINBOWS ARCH-SHAPED?

Rainbows are arched due to the way sunlight hits raindrops. It bends as it passes through because it slows during this process. Then, as the light passes out of the drop, it bends again as it returns to its normal speed.

How hot was the hottest day in history?

58°C (136°F)

Recorded on 13 September 1922 in Al Aziziyah, Libya

What's the difference between rain, sleet and snow?

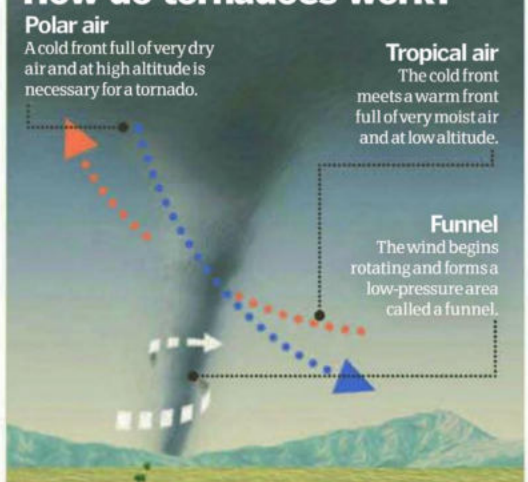
When it comes to precipitation, it's all about temperature. When the air is sufficiently saturated, water vapour begins to form clouds around ice, salt or other cloud seeds. If saturation continues, water droplets grow and merge until they become heavy enough to fall as rain. Snow forms when the air is cold enough to freeze supercooled water droplets – lower than -31 degrees Celsius (-34 degrees Fahrenheit) – then falls. Sleet is somewhere in between: it starts as snow but passes through a layer of warmer air before hitting the ground, resulting in some snow melting.

© SPL

What are gravity wave clouds?

Gravity waves are waves of air moving through a stable area of the atmosphere. The air might be displaced by an updraft or something like mountains as the air passes over. The upward thrust of air creates bands of clouds with empty space between them. Cool air wants to sink, but if it is buoyed again by the updraft, it will create additional gravity wave clouds.

How do tornadoes work?



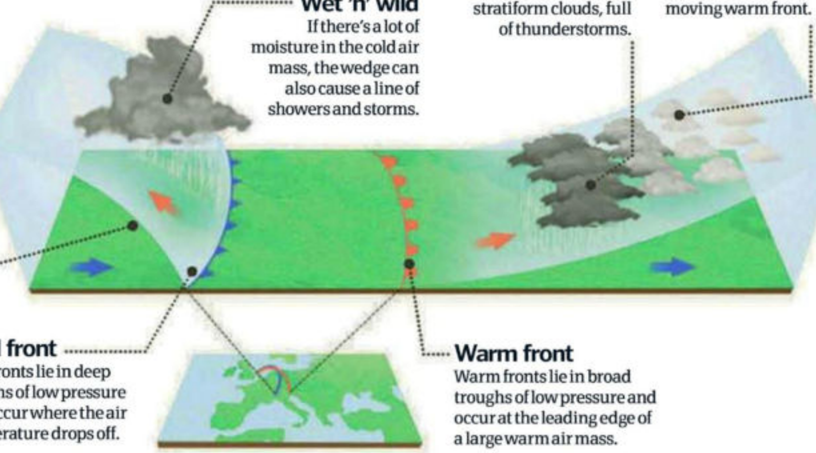
Tornadoes start out with severe thunderstorms called supercells. They form when polar air comes in contact with tropical air in a very unstable atmosphere. Supercells contain a rotating updraft of air that is known as a mesocyclone, which keeps them going for a long time. High winds add to the rotation, which keeps getting faster and faster until eventually it forms a funnel. The funnel cloud creates a sucking area of low pressure at the bottom. As soon as this funnel comes in to contact with the Earth, you have a tornado.

Why is it so quiet after it snows?

It's peaceful after snowfall as the snow has a dampening effect; pockets of air between the flakes absorb noise. However, if it's compacted snow and windy, the snow might actually reflect sound.

What is a weather front?

A weather front is the separation between two different masses of air, which have differing densities, temperature and humidity. On weather maps, they're delineated by lines and symbols. The meeting of different frontal systems causes the vast majority of weather phenomena.



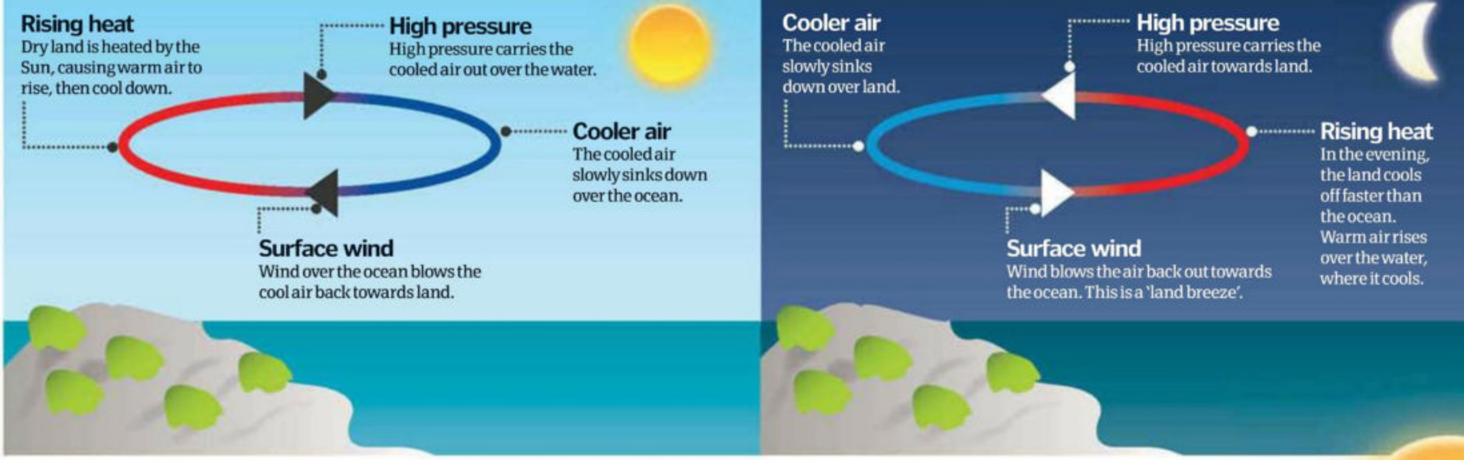
DAY AT NIGHT

Noctilucent clouds occur when icy polar mesospheric clouds – the highest clouds in the Earth's atmosphere at 76-85 kilometres (47-53 miles) – refract the fading twilight after the Sun has set, temporarily illuminating the sky.

© Martin Koitmäe

DID YOU KNOW? Fog is made up of millions of droplets of water floating in the air

What is a sea breeze?



What is the eye of a storm?

The eye is the calm centre of a storm like a hurricane or tornado, without any weather phenomena. Because these systems consist of circular, rotating winds, air is funnelled downward through the eye and feeds back into the storm itself.

The eye at the centre of a hurricane tends to be 20-50km (12-31mi) in diameter

© NASA

© SPL

What are red sprites and blue jets?

These are both atmospheric and electrical phenomena that take place in the upper atmosphere, and are also known as upper-atmosphere discharge. They take place above normal lightning; blue jets occur around 40-50 kilometres (25-30 miles) above the Earth, while red sprites are higher at 50-100 kilometres (32-64 miles). Blue jets happen in cone shapes above thunderstorm clouds, and are not related to lightning. They're blue due to ionised emissions from nitrogen. Red sprites can appear as different shapes and have hanging tendrils. They occur when positive lightning goes from the cloud to the ground.

Does lightning ever strike in the same place twice?

Yes, lightning often strikes twice in the same location. If there's a thunderstorm and lightning strikes, it's just as likely to happen again. Many tall structures get struck repeatedly during thunderstorms, such as New York City's famed Empire State Building or NASA's shuttle launch pad in Cape Canaveral, Florida.

How cold was the coldest day in history?

-89°C (-129°F)

Recorded on 21 July 1983 at Vostok II Station, Antarctica

Why does the Sun shine?

The Sun is a super-dense ball of gas, where hydrogen is continually burned into helium (nuclear fusion). This generates a huge deal of energy, and the core reaches 15 million degrees Celsius (27 million degrees Fahrenheit). This extreme heat produces lots of light.

WHY ARE CLOUDS FLUFFY?

Fluffy-looking clouds – the big cotton-ball ones – are a type called cumulus. They form when warm air rises from the ground, meets a layer of cool air and moisture condenses. If the cloud grows enough to meet an upper layer of freezing air, rain or snow may fall from the cloud.

WHAT'S IN ACID RAIN?

Acid rain is full of chemicals like nitrogen oxide, carbon dioxide and sulphur dioxide, which react with water in the rain. Much of it comes from coal powerplants, cars and factories. It can harm wildlife and also damage buildings.

WHY CAN I SEE MY BREATH IF IT'S COLD?

Your breath is full of warm water vapour because your lungs are moist. When it's cold outside and you breathe out, that warm vapour cools rapidly as it hits the cold air. The water molecules slow down, begin to change form, and bunch up together, becoming visible.

WHAT IS THE GREEN FLASH YOU SEE AS THE SUN SETS SOMETIMES?

At sunsets (or indeed rises), the Sun can occasionally change colour due to refraction. This can cause a phenomenon called green flash. It only lasts for a second or two so can be very tricky to spot.

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

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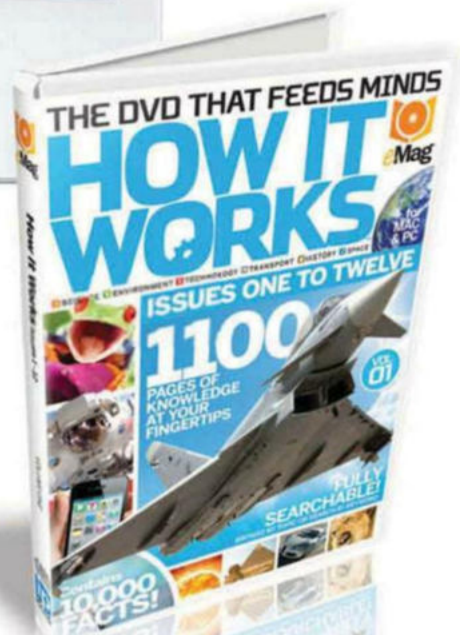

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IMAGINE PUBLISHING

1. CHATTY

African Grey
This parrot is typically found in the rainforests of West Africa but is a very popular pet bird. It has a reputation for being both vocal and brainy.

© Tyrminatr

2. CHATTIER

Quaker parrot
With a vocabulary of around 500 words, Quaker parrots can verbally inform their owners of a wide variety of emotions and needs.

© diegodobelo

3. CHATTIEST

Budgerigar
Male budgies are considered to be one of the best talker birds around, holding the world record for vocabulary. However their voices are quite fast and high-pitched.

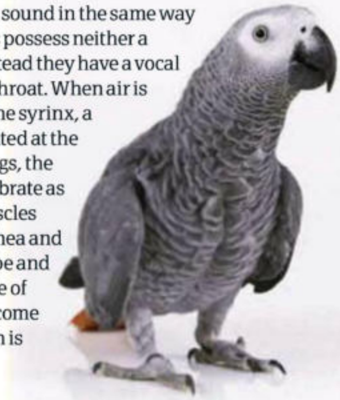
© Arnot T Fairchild

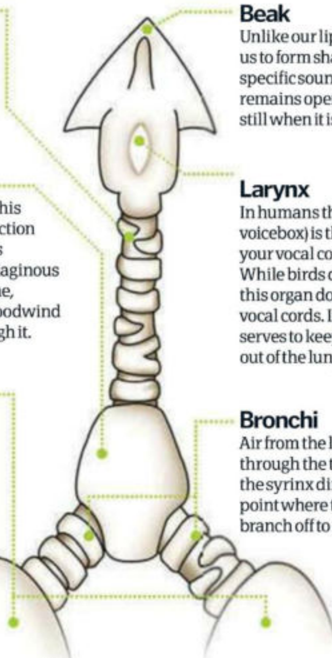
DID YOU KNOW? In 1995, a budgie called Puck was recognised as having the largest vocabulary of any bird with over 1,700 words

How are parrots able to talk?

Discover the physiology of this bird that enables it to mimic human speech

While parrots do seem to make noises that sound like words, they do not create the sound in the same way that we do. For starters, birds possess neither a voicebox nor vocal cords. Instead they have a vocal organ called the syrinx lower down the throat. When air is expelled from the parrot's lungs across the syrinx, a wide range of noises can be formed. Located at the bottom of the trachea, just before the lungs, the syrinx is a bony structure whose walls vibrate as air passes through it. Parrots use the muscles around the syrinx (at the base of the trachea and the top of the bronchi) to change the shape and depth of the space, producing a multitude of different sounds. Changes in resonance come from the variations in air pressure, which is controlled by the bird's lungs.





Trachea
The trachea, or windpipe, is a tube that runs from the back of the bird's throat (pharynx) to the syrinx. Sound is created by air waves leaving the trachea.

Syrinx
The syrinx is a bird's vocal organ. This resonant hollow is found at the junction between the bronchi and the bird's trachea. Inside the syrinx is a cartilaginous flap called the tympanic membrane, which vibrates like the reed in a woodwind instrument when air passes through it.

Lungs
Sound is produced by air passing through the syrinx from the lungs. Birds can control the air pressure in each lung individually, enabling them to adjust the resonance of the sounds they make. This also means they can make more than one noise at a time.

Beak
Unlike our lips, which enable us to form shapes to create specific sounds, a parrot's beak remains open but relatively still when it is speaking.

Larynx
In humans the larynx (or voicebox) is the organ in which your vocal cords are found. While birds do have a larynx, this organ does not feature vocal cords. Instead the larynx serves to keep food and water out of the lungs.

Bronchi
Air from the lungs travels through the two bronchi into the syrinx directly above the point where the bronchi branch off to each lung.

How do lionfish survive?

A fish of many names, but there's no mistaking this sea creature is a born survivor

With its graceful fins and zebra-like stripes, the lionfish may not look particularly feline, but compared to some of its other nicknames – like the dragonfish and, believe it or not, even the turkeyfish – it doesn't seem so far-fetched. Perhaps the most appropriate moniker that this sea creature goes by is scorpionfish (the wider family to which this species belongs), because it can deliver a very nasty sting.

However, the series of needle-like spines (up to 18), which line its upper body and can each inject a dose of powerful venom, are not used to kill. This weapon is purely a defensive one deployed when the lionfish feels threatened. Although being on the receiving end of these spines is very painful for humans – potentially leading to sickness or breathing problems – fatalities are extremely rare.

That's not to say the lionfish isn't an adept killer of other marine life. It is very much an ambush predator where any prey – mainly consisting of fry and small crustaceans like prawns – that ventures too close falling victim to this species' lightning-fast reflexes. Once in the lionfish's range, there's little chance of a fight as their quarry is gulped whole.

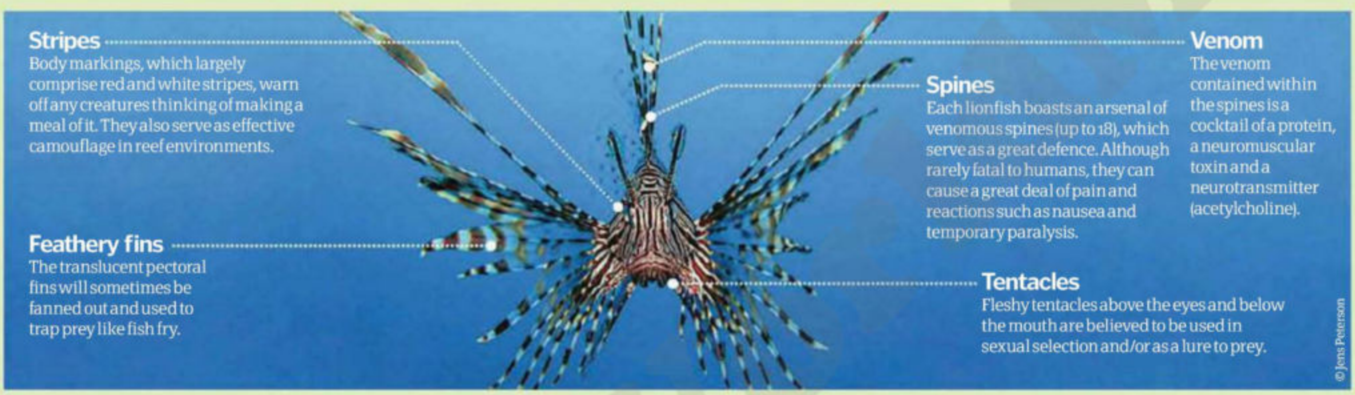
Originating from the Indo-Pacific region, since the Nineties lionfish populations have seen a boom in other tropical seas like the Caribbean and the Gulf of Mexico. Most likely this is a result of pet owners releasing fish that have grown too big for their tanks into the sea. It's a major concern to conservation groups, as not only does this invasive species have few predators, but it has a very high reproduction rate – indeed, females can spawn up to 30,000 eggs in one week alone (that equates to roughly 1.5 million eggs a year).

The statistics...

© OpenCage

Lionfish

Genus: Pterois
Length: 30-38cm (11.8-15in)
Weight: Up to 1.2kg (2.6lb)
Diet: Carnivore (eg fish, shrimp)
Life span in wild: Up to 15 years



Stripes
Body markings, which largely comprise red and white stripes, warn off any creatures thinking of making a meal of it. They also serve as effective camouflage in reef environments.

Feathery fins
The translucent pectoral fins will sometimes be fanned out and used to trap prey like fish fry.

Spines
Each lionfish boasts an arsenal of venomous spines (up to 18), which serve as a great defence. Although rarely fatal to humans, they can cause a great deal of pain and reactions such as nausea and temporary paralysis.

Venom
The venom contained within the spines is a cocktail of a protein, a neuromuscular toxin and a neurotransmitter (acetylcholine).

Tentacles
Fleshy tentacles above the eyes and below the mouth are believed to be used in sexual selection and/or as a lure to prey.

© Jens Peterson

1. NOSE
Elephants
Elephant trunks are a fusion of nose and top lip. They feature four major external muscles and a network of small internal muscles for added agility.

2. TONGUE
Giraffes
A very useful prehensile appendage, the giraffe's tongue is super-long – up to 50cm (20in) – and very supple. It's used to strip leaves from high branches.

3. LIPS
Camels
Both camels and horses use muscular lips to sort through what they want to eat: for camels, flexible lips are handy for negotiating thorny desert plants.

DID YOU KNOW? *The word 'prehensile' comes from 'prehendere', the Latin for 'to grasp'*

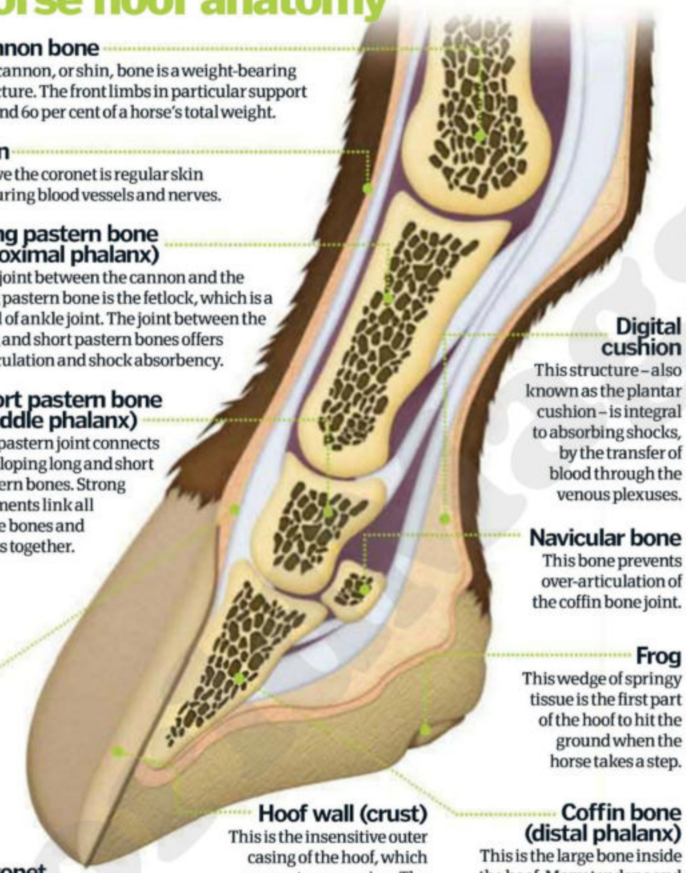
What's inside horse hooves?

Discover the structure of a horse's feet and why fitting horseshoes doesn't cause pain

Horse hooves are the thick horny coverings that protect the end of the horse's leg and also provide shock absorbency. Horse hooves are made of a tough protein called keratin – the same stuff our nails and hair are made of. The keratin in a horse's hoof is layered in horizontal sheets, in order to add strength and minimise the extent of any damage that could split the hoof irreparably in the event of a crack.

Horses are digitigrade – ie they walk on their tiptoes – and therefore require a spongy pad beneath the heel on which to walk. While the outer wall of the hoof is insensitive – much like human hair and fingernails – the inner parts can feel pain. Therefore, when a farrier fits a horseshoe to the hoof, they do so by hammering the nails into only the outer wall of the hoof. Horseshoes, which are often made of steel these days, offer added shock absorbency as well as traction on the ground. These curved metal bands come with between six and eight square nail holes through which the metal pins can be slotted. One by one, the nails are hammered into the hard, nerve-free outer wall of the hoof, securely fastening the shoe to the creature's hoof.

Horse hoof anatomy



Cannon bone
The cannon, or shin, bone is a weight-bearing structure. The front limbs in particular support around 60 per cent of a horse's total weight.

Skin
Above the coronet is regular skin featuring blood vessels and nerves.

Long pastern bone (proximal phalanx)
The joint between the cannon and the long pastern bone is the fetlock, which is a kind of ankle joint. The joint between the long and short pastern bones offers articulation and shock absorbency.

Short pastern bone (middle phalanx)
The pastern joint connects the sloping long and short pastern bones. Strong ligaments link all these bones and joints together.

Digital cushion
This structure – also known as the plantar cushion – is integral to absorbing shocks, by the transfer of blood through the venous plexuses.

Navicular bone
This bone prevents over-articulation of the coffin bone joint.

Frog
This wedge of springy tissue is the first part of the hoof to hit the ground when the horse takes a step.

Coronet
The coronet marks where the hoof meets the leg. The wall of the hoof grows out of this small bulge.

Hoof wall (crust)
This is the insensitive outer casing of the hoof, which never stops growing. The front-facing walls of the fore-hooves are slightly thicker than the rest.

Coffin bone (distal phalanx)
This is the large bone inside the hoof. Many tendons and ligaments are attached to this and a network of blood vessels run through it.

Spider monkeys spend a lot of their time in the trees so the extra grip a prehensile tail affords can prove a real asset

How do prehensile tails grip?

Learn about the creatures whose tails work like additional limbs

Animal tails perform a vast array of physical functions, from working as a cheetah's counterbalance when cornering at high speeds to delivering a powerful blow in the case of the crocodile, or even communicating emotion, when a pet hound wags its tail. An animal with a prehensile tail, however, has a special ability to grip on to things with its specialised appendage – using it as a kind of extra limb.

Among other animals, fully prehensile-tailed creatures include species from the New World order of primates, which are native to rainforest regions in South America. Here, where the branches of the tree canopy can be widely spaced, animals had to develop a suitable mechanism to assist them in traversing these large gaps in the rainforest over many thousands of years. Spider monkeys, for instance, use their agile tails for additional balance and locomotion when swinging through the treetops.

Such a tail is required to suspend the entire weight of a creature and so the skeleton and muscular structure of prehensile tails must be resistant to both torsion and bending, and capable of generating higher forces than regular tails. An opossum, for example, dangles upside down by its tail while using its hands to pick food. The tip of the tail can curl round branches and trunks and some prehensile-tailed mammals even have patches of bare skin or scales – instead of fur – for a non-slip grip on surfaces such as branches.

"When coral dies, the hard, chalky skeletal remains are left behind and new polyps will then grow on top"

What is coral?

Are these brightly coloured marine organisms animal, vegetable or mineral, and how do they manage to support the world's richest ocean habitats?

While corals may look like rocks and share several characteristics of plants, they are in fact animals. To be exact they are aquatic marine invertebrates (known as polyps) that live in the warm shallows of the clear coastal waters around the world. A huge number of marine organisms make their home among the corals, making reefs some of the most abundant and varied habitats on Earth.

Because the nutrients on which plankton need to feed dissolve better in deeper, cooler water, the warmer layers become a less attractive spot for the huge numbers of floating plankton to occupy. Therefore, the upper shallows remain warm and clear – the ideal living conditions for microscopic algae, which use sunlight to combine carbon dioxide and water to create their own food source, which they share with their coral. Corals live in partnership with single-celled zooxanthellae algae, which are also responsible for the bright colours seen in this photo. If the algae die the coral will turn white, a damaging effect known as coral bleaching.

Like jellyfish, corals are cnidarians, except they are rooted to the spot by a tube attached to a surface (usually rock), rather than floating freely like jellyfish. Cnidarians consist of a simple body, featuring a central mouth opening that is surrounded by stinging tentacles.

The coral polyp is the soft individual organism that forms from a single-celled alga and lives within a larger community of similar polyps called a colony. They use calcium and a variety of other minerals in the seawater – together with the food waste they produce – to construct their own protective calcium carbonate skeleton shelters in which to live.

When coral dies, the hard, chalky skeletal remains are left behind and new polyps will then grow on top of these. Sedimentary limestone rock is formed when the coral skeletons are compacted over many thousands of years. Over hundreds of thousands of years, a single colony of polyps can grow big enough to eventually link up with other colonies to form a large coral reef.

While coral can take centuries to grow, it has a multitude of natural enemies and can quickly be destroyed by rising ocean temperatures, pollution and physical destruction due to harvesting for souvenirs and medicine, or accidental damage by divers and boats.

Coral can play home to a vast array of marine life, providing both food and shelter

CORAL'S DARK SIDE

Though coral is among the world's most fragile organisms, it can be predatory. Coral not only senses movement, but it can also detect waterborne chemicals from passing sea creatures. Using barbed, venomous tentacles it can reach out and grab its prey.

DID YOU KNOW? *While coral amounts to only around 0.2 per cent of the ocean floor, it contains a quarter of Earth's marine life*

A coral reef in the clear shallow waters common around the Caribbean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How jousting worked

Welcome to...
HISTORY

We've all seen the knights in movies, charging at each other on horseback to win the love of the crowd and perhaps a special lady, but was it all so romantic in reality? Also find out how the earliest coins were first hammered into shape, see the inner workings of the cuckoo clock and meet a heavily armoured, vegetarian dino called the triceratops.

LEARN MORE

Jousting explained

High-speed, brutal and theatrical – it's easy to see why this martial sport was so popular in the Middle Ages

Jousting was a martial sporting event undertaken between two horsemen using lances, each aiming to strike the other and unhorse him. It worked either as a single event or as part of a larger tournament, the latter involving other athletic disciplines such as hand-to-hand combat.

The joust itself, however, worked on a point-scoring system, with each true blow struck on the opponent generating a number of points for the striker, the total depending on where the blow landed. So, if a rider hit his opponent on the helmet he was awarded two points, while if he struck them on the breastplate only a single point would be awarded. If a rider unhorsed his opponent with a strike then he was awarded three points and the match was considered over. Importantly, however, only true blows generated points, with a true blow consisting of the lance shattering on impact. Glancing blows, low blows and any strike that did not shatter the lance were not counted.

For each joust both horsemen were equipped with a trio of lances, to be used over a series of three charges. All lances were measured before each joust to ensure they were of equal length and therefore no reach advantage could be sought. In addition, strict rules governed each meeting, with only the horseman's squire (assistant) allowed to hand him new lances or help him in the event of an unhorsing. As part of these rules, it was also mandatory that any knight competing own the horse and armour he was using, as in the event that they were unhorsed, their opponent could demand both as a victory trophy. Of course, all these rules came behind the first and most important, which stated that only noblemen could compete.

If the joust was held as part of a larger competition, the other key event was the hand-to-hand combat match. This worked along a similar set of rules to the joust proper, with the first knight to land three blows on his opponent the victor. Which weapons and styles were allowed were dictated before the tournament.

Historically, jousting emerged out of the High Middle Ages (1000-1300) and was based on the military use of the

5 TOP FACTS JOUSTING

Jousting jeopardy

1 Jousting tournaments in the High Medieval period were considerably rougher and more dangerous than the more chivalric events held in the Late Medieval period.

A question of honour

2 By the 1390s combat in jousts was generally expected to be non-lethal, with any defeated opponent expected to honourably yield to the more dominant fighter.

Beyond the main event

3 Despite the main event in any jousting tournament being the joust proper, there were other subsidiary events, including foot combat, with the first to land three blows the winner.

Etymology

4 The term 'joust' is believed to have derived from the Old French word 'joster', which itself is derived from the Late Latin 'iuxtare', meaning to approach and/or to meet.

Lance-a-lot

5 Jousting lances were often made from ash wood, however unlike their military predecessors, they were not fitted with sharp iron or steel tips but rather blunt ones.

DID YOU KNOW? Jousting was phased out in France after King Henry II was mortally wounded in a tournament in 1559

Jousting armour breakdown

Being hit with a lance while jousting was akin to being struck by a sledgehammer, requiring knights to bolster their steel plate to avoid injury or even death.

Helmet

Due to bonus points being awarded for a head strike, jousting helmets were heavily modified to add more protection. Armets and close helms were popular, as – aside from being sharply angled – they were equipped with a pivoting visor, allowing successful knights to present themselves to the audience post-battle.

Gorget

The gorget was a steel collar designed to protect the knight's throat. It slotted into the suit of armour underneath the breast- and backplates, and typically comprised layered and angled steel plates.

Pauldron

Due to the high likelihood of being struck in the shoulder, pauldrons (shoulder guards) were heavily strengthened. Thicker, ridged steel was used, often with a fluted auxiliary layer designed to deflect lance strikes.

Besagew

Due to reduced necessity of movement while charging in horseback jousts, knights would often equip besagews (small circular shields) to their armour. These were designed to provide extra protection at joints – such as the armpit – where gaps in the plate could be exploited.

Lancer

A unique adaptation to standard plate armour was a lance holder, which was positioned beneath the right-arm pauldron. The steel hook was welded to the breastplate and helped support the lance while charging, allowing for a greater strike accuracy.

Cuirass

The technical name for the armour's breast- and backplates, the cuirass was one of the core components to any jousting armour. The breastplate was often smoothly angled away from a central apex to deflect blows.

Gauntlet

Jousting gauntlets were designed to maximise the combatant's grip of their lance and, as such, Almain rivet type designs were commonly used. These consisted of layered, overlapping steel plates augmented with reinforced knuckle and fingertip caps, which covered only the top and sides of the hands, leaving the underside free to grip through a leather/fabric glove.

Sabaton

The sabaton was the part of the armour that covered the jouster's foot. They were commonly made from riveted iron plates. Their design varied depending both on the era and the class of the jouster, with high-born members of the aristocracy allowed to sport long tapered sabatons, while the standard gentry were only allowed to wear short, flat-tipped varieties.

lance by heavy cavalry. Up until the 17th century, jousting gradually evolved from a blood sport into the sporting form of chivalry for which it is now remembered. For example, by the time of Queen Elizabeth I's reign (1558-1603), jousting had been heavily romanticised and was more a form of entertainment, rather than proof of military prowess.

Interestingly, today jousting is seeing something of a renaissance, with dedicated jousting clubs organising competitions and medieval re-enactment events held worldwide.

"Only true blows generated points, with a true blow consisting of the lance shattering on impact"

How were the original coins made?

When did milling begin and how did ancient criminals profit from it?

Today, our currency is pressed out of long sheets of metal and stamped under pressures of up to 360 tons per square inch in automated machines. But before Matthew Boulton's steam-powered minting process and Peter Blondeau's hand-cranked machinery, coins were struck individually by hand.

Carefully weighed circular blanks of metal from the forge were placed between two hardened metal blocks, one with the reverse design and the obverse design on the other. The top die was then struck hard with a hammer so that the softer metal of the coin blank took on the design on both sides. The process – which was called milling – was comparatively time-consuming and was also fraught with errors: coins were frequently struck off-centre, double-struck or cracked.

Worse still for the authorities, because gold and silver were used in the higher denominations and because no two coins were alike, the act of 'clipping' the edges of precious metal coins, or 'sweating' silver coins (shaking a bag of silver and collecting the dust), was common practice among the unscrupulous, who could then profit by spending the coin at its face value while pocketing the precious remains.

Coin milling in action

Hammer Modern minting methods can apply hundreds of tons per square inch to a blank. Soft metals only require the force of a hammer blow, though.

Upper die Held by an assistant, the upper die impressed the coin reverse.

Blank Prior to striking, the blank coin was also known as the flan, or planchet.

Lower die This was usually set into an anvil or wooden block for added stability.

This traditional tannery in Marrakech, Morocco, is surprisingly colourful, considering the animal waste used in the process

© Bernard Gagnon

How was leather manufactured?

Hold your nose as we reveal the rather revolting process of tanning leather

Machinery and chemicals have made the preparation of animal skin for human use a far less gory process in this day and age. But for hundreds of years, tanneries were relegated to the outskirts of a town because of the foul materials used in the process. Fresh from the slaughtered animal (cow, deer, rabbit or any creature with a workable skin), the skin would typically be stiff with gore, so the remaining flesh was scraped away, while any hair was removed by soaking the skin in urine.

Chicken faeces or other animal dung was then mixed with water in vats and kneaded into the skins by the tanner, who worked the leather into the vile concoction with his bare feet, like the way a worker would squeeze grapes at a vineyard. Animal faeces – especially that of dogs – contains an enzyme that breaks down the collagen in the skin, making it soft and pliable. In some cases, the mashed brain of the animal slaughtered was used to make buckskin or a fur hide, with the lecithin in the organ softening the surface of the hide. Finally, a tanning agent like cedar oil (or a similar natural tannin) was applied while the leather was being stretched in order to keep the material supple.

5 TOP FACTS CUCKOO CLOCKS

Prince
1 The first known description of a modern cuckoo clock comes from a 17th-century German nobleman, who wrote of Prince Elector August von Sachsen owning one.

Black Forest
2 Cuckoo clocks popularity grew during the 18th century, with Germany's Black Forest at the heart of production. Today they are highly prized and can cost thousands of pounds.

Chalet
3 Through the 20th century cuckoo clocks were commonly built in the shape of a wooden chalet, a style that originated in Switzerland towards the end of the 1800s, where they were sold as souvenirs.

Minimalist
4 Today, cuckoo clock design has become more varied both in form and function, with traditional and chalet, along with more minimalist and modern, timepieces all available.

Totally cuckoo
5 The world's most extensive and finest collection of cuckoo clocks (with both old and new models) is at the Cuckooland Museum in Cheshire, England.

DID YOU KNOW? *The creation of the cuckoo clock is credited to Ancient Greek mathematician Ctesibius*

Cuckoo clocks explained

How do these bird-ejecting timepieces work?

A cuckoo clock is a specialised type of pendulum-regulated (traditionally) timepiece that, as well as striking the hour like a normal clock, releases a small model cuckoo and its audible call too. The clock works through a series of internal and external components that, together, eject the cuckoo and play its call in time with the faceplate's hands.

The cuckoo clock was invented in its 'modern' form during the 16th century in Germany, and since has diversified into three main types: Black Forest, Swiss chalet and modern quartz.

The first type is considered both the most traditional – it was in the Black Forest area that the first modern cuckoo clocks were created – and most valuable, as all cuckoo clock manufacture in the region is quality controlled. These clocks have full mechanical movements, requiring them to be frequently wound, and are driven by weights that hang down beneath the clock. These movements come in two distinct types: one-day and eight-day.

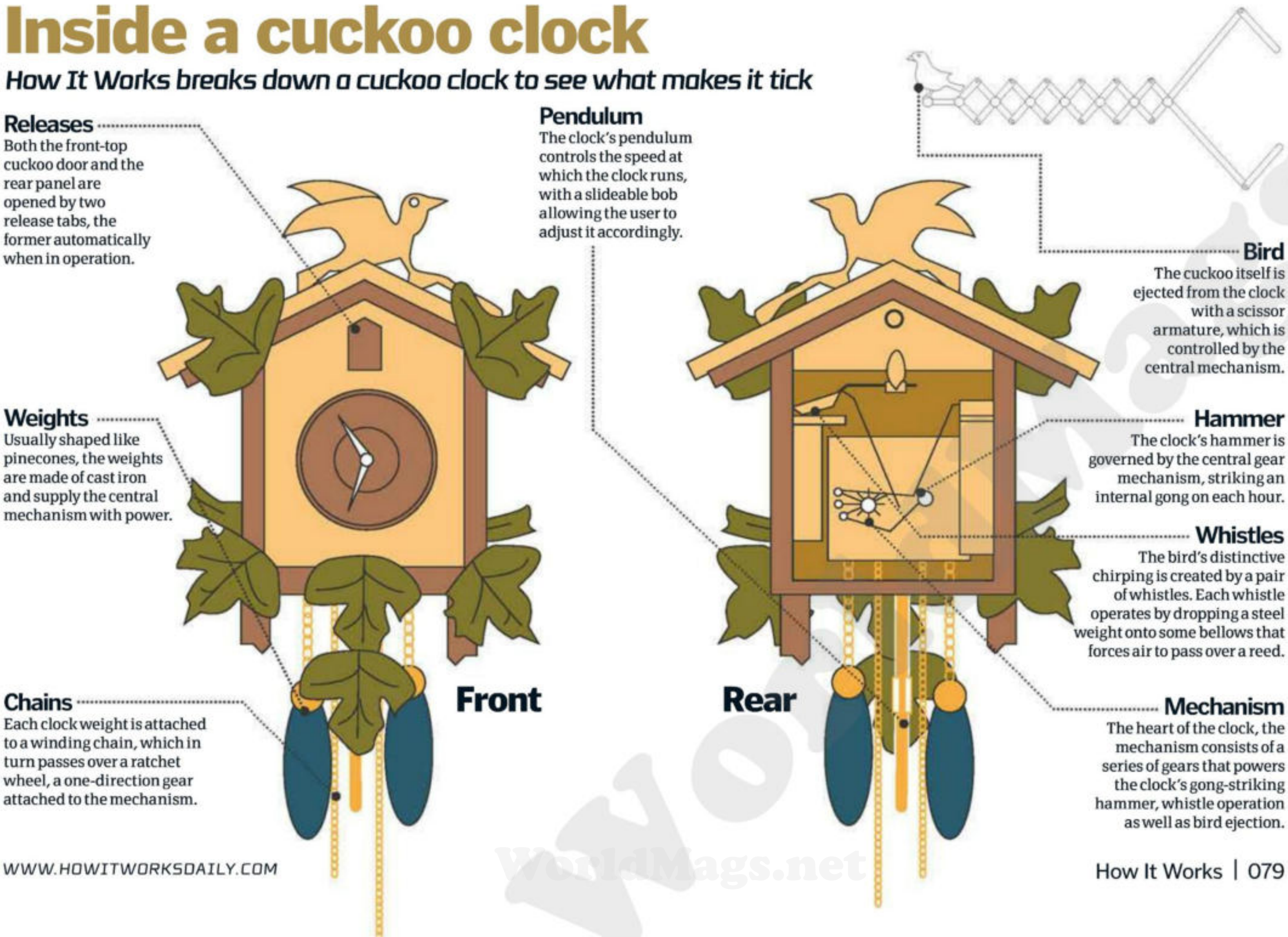
The second type is the chalet cuckoo clock, which was invented in the late-19th century in Switzerland. These clocks resemble wooden chalets and use either mechanical or quartz movements depending on their quality. A quartz movement differs markedly from a mechanical one in that it is powered by batteries rather than by winding and weights. The quartz movement works by using an electronic oscillator that is regulated by a quartz crystal to keep time, the oscillator creating a signal with a very precise frequency. Chalet cuckoo clocks also differ from Black Forest varieties in that they commonly have extra moving model features in addition to the traditional bird, such as woodcutter and housemaid figures.

The newest variant of cuckoo clock is the modern quartz. These tend to be more pared back in design and feature non-traditional internal mechanisms – for example, modern quartz cuckoo clocks produce their birdsong electronically via a digital recording, rather than the traditional dual bellows array.

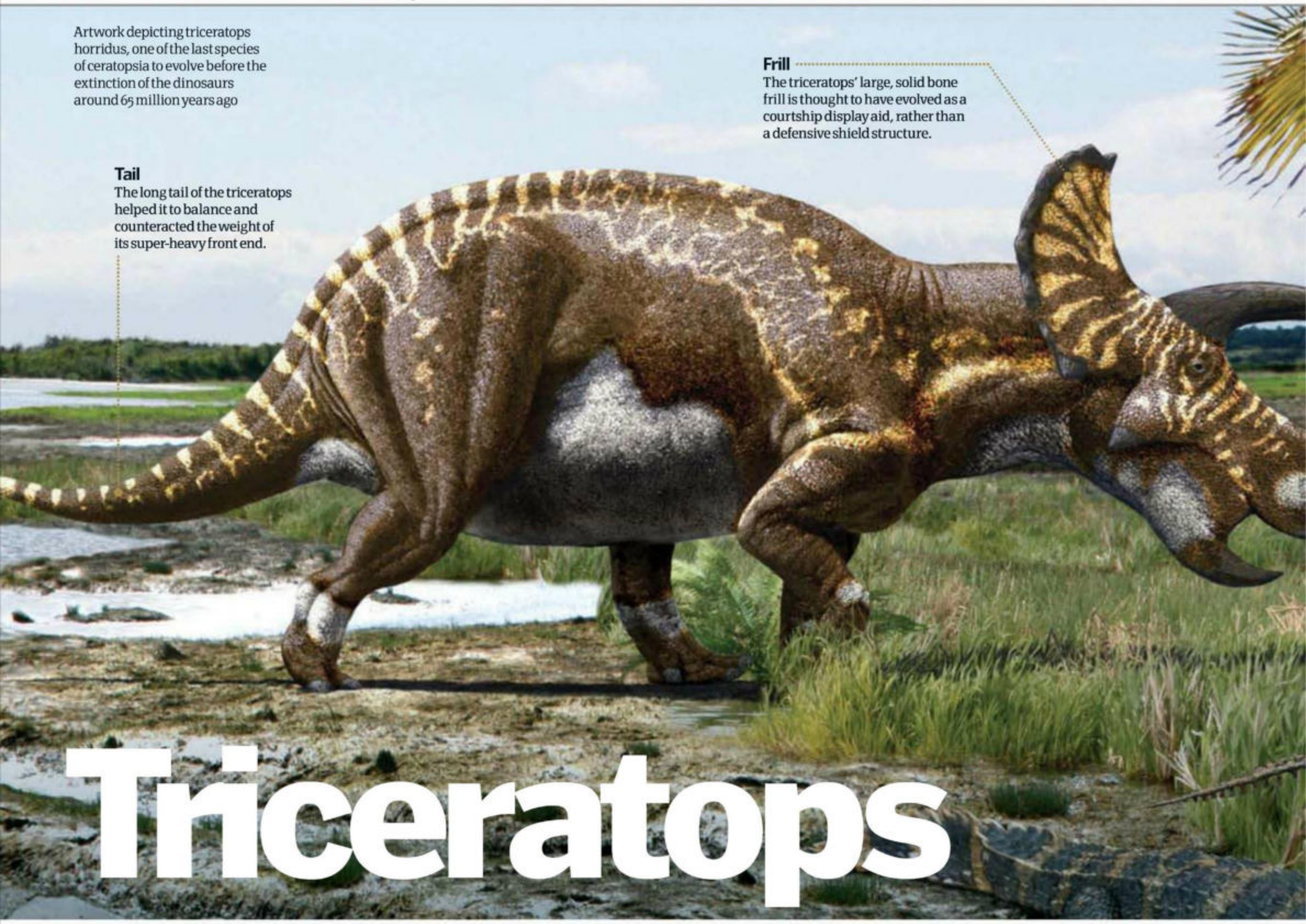

The Swiss chalet variant of cuckoo clock often incorporates other figures, such as a bride and groom in this example

Inside a cuckoo clock

How It Works breaks down a cuckoo clock to see what makes it tick



> "These traits made triceratops capable of puncturing flesh and shattering bone"



Artwork depicting triceratops horridus, one of the last species of ceratopsia to evolve before the extinction of the dinosaurs around 65 million years ago

Triceratops

One of the most well-known dinosaurs, the triceratops was a herbivorous titan that was very well equipped for a fight

Triceratops is a genus of herbivorous dinosaur that comprises two validated species – triceratops horridus and triceratops prorsus, both of which roamed Earth during the Late Cretaceous period (68-65 Ma) before being eradicated in the K-T mass-extinction event that wiped out all dinosaurs.

Triceratops were large, rhinoceros-like animals that weighed many tons – a fully grown adult would be expected to weigh in the region of seven tons. They were heavily armoured with reinforced bone horns, which could exceed 70 centimetres (28 inches) and a solid bone frill, and hugely powerful thanks to their sturdy frame. These traits, combined, made both species of triceratops a fearsome foe to potential predators, capable of puncturing flesh and shattering bone with their sharp horns when charging.

In terms of anatomy (for a comprehensive rundown, see the 'Triceratops anatomy' illustration), the triceratops genus is incredibly interesting, not least because many of its parts' functions are still debated today in the field of palaeontology. A good example of this can be seen by analysing a typical triceratops skull, which – aside from typically measuring a whopping two metres (6.6 feet) in length – sported three horns as well as a fluted, extravagant rear frill.

The horns, from which the genus gets its name, and frill have been successfully argued by palaeontologists to have been used for self-defence against predators, with close examination of unearthed specimens revealing battle scars, cuts, punctures and cracks. However, modern scholars also postulate that both skull features, along with the elongated nature of the skull itself, most likely also evolved as courtship aids, with potential mates selected on the size and shape of these features. It has also been suggested that the frill may have helped triceratops regulate their body temperature in a similar manner to the plate-laden stegosaurus (whose name translates as roof, or covered, lizard).

Other anatomical areas of interest lie in this dinosaur's large bird-like beak and hips. Indeed, it is because of these particular features that this genus has been used as a reference point in the definition of all dinosaurs – ie all dinosaurs are descendants of the most recent common ancestor of triceratops and, as such, this common ancestor is also that of birds prevalent throughout the world today. It's important to note here that modern birds did not descend from triceratops directly, but rather from its common ancestor with all other dinosaurs; today's birds in fact originate from saurischian dinosaurs.

5 TOP FACTS
TRICERATOPS

Fight!
1 Artist Charles R Knight famously depicted a triceratops and T-rex squaring up for a fight in a 1901 painting. In reality, these two dinosaurs were not prominent adversaries.

Range
2 The triceratops genus existed during the Late Cretaceous period in what is now North America. Many of today's finds are discovered in the Hell Creek Formation in Montana, USA.

Valid
3 Despite many species being named, only two species of triceratops are considered valid today by palaeontologists. These are triceratops horridus (1889) and triceratops prorsus (1890).

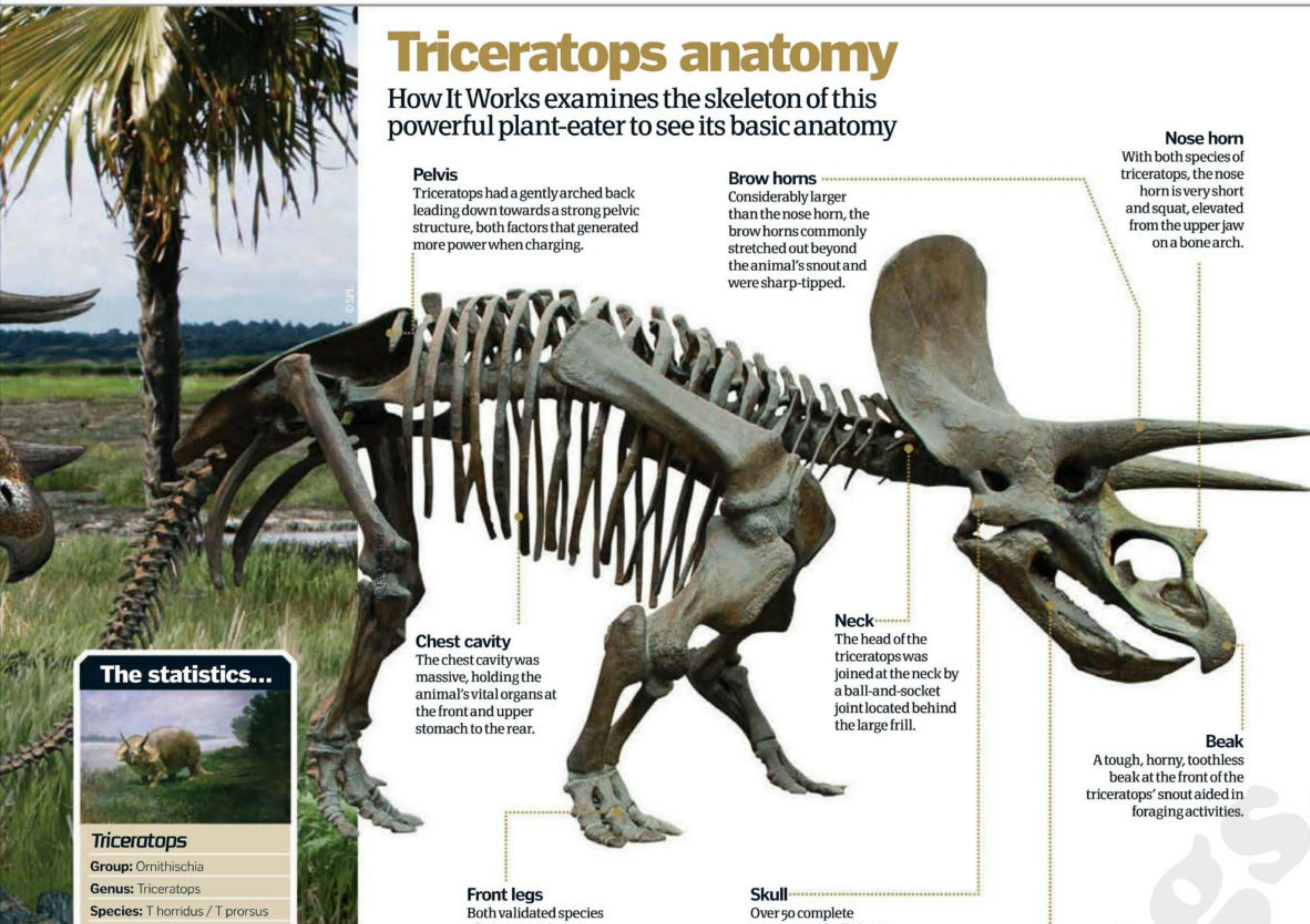
Origins
4 Today, the evolutionary origins of the triceratops are considered to be in Asia during the Jurassic period. However, they only became prominently horned animals in the Late Cretaceous.

Herd
5 Despite TV shows and Hollywood movies commonly depicting triceratops as herding animals, there is actually very little recorded evidence that supports this claim.

DID YOU KNOW? The first recorded triceratops remains discovered in the modern era were unearthed in 1887

Triceratops anatomy

How It Works examines the skeleton of this powerful plant-eater to see its basic anatomy



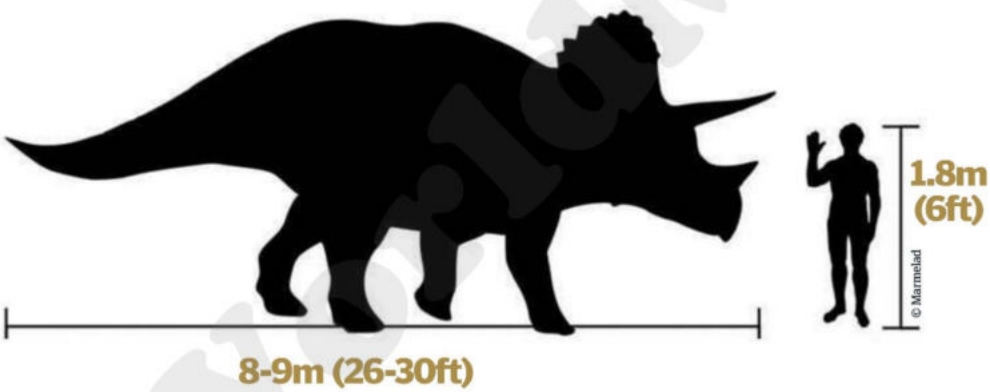
The statistics...

Triceratops

Group: Ornithischia
Genus: Triceratops
Species: T horridus / T prorsus
Range: Late Cretaceous
Length: 8m (26ft)
Height: 2.9m (9.5ft)
Weight: 6,350kg (14,000lb)

The fundamental diet of the triceratops was largely dictated by – and most likely co-evolved with – its low-slung posture and head position, which was located close to the ground. As a consequence of these factors, as well as its deep and narrow beak and sharp teeth batteries, both species of triceratops most likely consumed large amounts of low-growth ferns, palms and cycads, plucking the plants with their beaks and then shredding the fibrous material with their teeth.

The triceratops' main potential predators were carnivorous theropod dinosaurs such as the tyrannosaurus rex. However, while modern-day depictions of these two prehistoric titans are often far-fetched, triceratops specimens have been discovered with T-rex bite marks and even one where the herbivore had had one of its brow horns snapped off entirely.



BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has two degrees, one in Zoology and one in Real-time Computing, and he has been writing about science and technology for years. His sci-fi novel *A Jar Of Wasps* is published by Anarchy Books.

Shanna Freeman

Toddler-wrangler by day and writer by night, Shanna has never stopped asking questions. Now she has a curious child of her own, she's realising how much she must have tried her parents' patience!

Rik Sargent

Rik is an outreach officer at the Institute of Physics where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Mike Anderiesz

Mike has been a journalist and copywriter for over 15 years, writing for a range of publications and institutions including *The Guardian*, the BBC and Microsoft. His expertise lie in technology, computing and lifestyle products.

Aneel Bhangu

Aneel is a training academic surgeon working in London. His research interests include advanced cancers and medical statistics, with his clinical interests including planned surgery for rectal cancers and emergency surgery for trauma.

What is plasma?

Kev Smith

In physics, plasma is the fourth state of matter. All 'stuff' in the universe is made of matter, but we are only familiar with it being a solid, liquid or gas. Heating any gas to a high enough temperature will cause the electrons in atoms to be stripped away from their associated nuclei, leaving just protons and neutrons. These protons and neutrons are called ions and are positively charged due to the lack of negative electrons. Clouds of ions or electrons are known as plasma and only occur at temperatures over a few thousand degrees Celsius. The Sun, like most stars, is almost entirely plasma, making plasma the most abundant state of matter in the universe.

Rik Sargent

© NASA

The Sun is almost wholly composed of plasma

Why do irons work so much better when hot?

Richard Hill

Cloth fibres are bound together by chemical bonds, the polymer strands becoming fixed in unnatural shapes (wrinkles) as the fabric bends. These bonds are weakened by heat, so when a hot iron is applied, the cross-linking between the fibres is loosened, allowing the weight of the iron to force them into a new, flatter shape. As soon as the heat is removed, the polymers re-bind into their new position and, voila, a freshly pressed shirt, skirt or pillowcase. Apply weight without heat and the job is much harder unless water is added too – hence the wrinkle-busting power of the steam iron.

Mike Anderiesz

A recent study suggests that a peacock's plumage doesn't up its chances of finding a mate, but is this the end of the 'tail'?

Why do peacocks have such unusual feathers?

David Hendy

The standard explanation, first posited by Charles Darwin, is that the peacock is advertising to the peahen what a good mate he will make. Peahens choose the males with the most impressive tails because it demonstrates that they are healthy and strong enough to drag such an encumbrance through the jungle, and also because the peahen wants to produce sons that will have big tails because then they will be successful in attracting mates themselves. This theory was recently challenged after a seven-year study in Japan found that large tails didn't make peacocks more successful in finding a mate. But that research has been criticised for ignoring colour and eyespot density and the consensus is still that the peacock tail is a result of sexual selection.

Luis Villazon

What causes the 'butterflies in my stomach' feeling?

As with many of our involuntary reactions, this relates back to the fight or flight instinct

Ben Hardy

"I've got butterflies in my stomach" – this relates to more than just that feeling you get when you're around someone you'd like to kiss, as the same feeling also comes when you're nervous (eg before an exam or the first day on a new job). These feelings are most likely related to the fight or flight reflex. When something stressful is about to happen (in evolution this would be fighting a predator/rival), the body switches into an 'action mode', which sends adrenaline speeding through your bloodstream. In addition, the autonomic nervous system diverts blood away from non-essential systems (such as your stomach and intestines) and sends it to the muscles and brain. The vagus nerve, which is a key mediator of this effect, slows stomach function, as well as increasing the heart rate. This may be the reason that your stomach, which doesn't need to be active during these situations, reports a different sensation to your brain.

Aneel Bhangu

Can we see both the Sun and the moon (when it isn't an eclipse)?

Starry-eyed truth

Yes! The moon is actually the second-brightest object in the sky after the Sun and you can see it most of the time… if you know when and where to look. How well you can see it depends on the phase of the moon. It orbits Earth once every 28 days (a lunar month), so there are times when it won't be visible during the day, or visible at all. But most of the time you can see it as it moves eastward, with the best visibility during the third or last quarter. Check a lunar calendar and look in the southern sky in the early morning (in the northern hemisphere).

Shanna Freeman

Why are some animals all white? Find out on page 84

BRAIN DUMP

Because enquiring minds want to know...

Can people in space burp?
Find out on page 85

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Why are some animals albino?

Joe Bulger

Although albinism is rare, many animals (including humans) are at risk of it. Being albino refers to a complete absence, or in some cases a reduction in the levels, of melanin that cause pigmentation of the skin, eyes and hair. This is due to a fault in the function of the enzyme that produces melanin. It is a genetic condition, caused by inheritance of two recessive genes, though this is a very rare occurrence. As well as lightening the colour of skin and hair, albinism can also affect the way the visual system develops and lead to sight problems.
Aneel Bhangu

Do we control our brains or do our brains control us?

Gukophoto

An experiment at the Max Planck Institute, Berlin, in 2008 showed that when you decide to move your hand, the decision can be seen in your brain, with an MRI scanner, *before* you are aware you have made a decision. The delay is around six seconds. During that time, your mind is made up but your consciousness doesn't acknowledge the decision until your hand moves. One interpretation of this is that your consciousness – the thing you think of as 'you' – is just a passenger inside a deterministic automaton. Your unconscious brain and your body get on with running your life, and only report back to your conscious mind when necessary to preserve a sense of free will. But it's just as valid to say that when you make a decision, there's always a certain amount of background processing going on, which the conscious mind ignores for convenience. In the same way, your eye projects an upside-down image onto your retina, but your unconscious brain turns it the right way around.
Luis Villazon

How would you put out a fire on the ISS?

Belinda Mitchell

Although to date there have been no fires on the ISS, it remains a dangerous possibility because even NASA has relatively little experience of fighting fire in space. On the plus side, flames burn at a lower temperature in space as they receive far less oxygen. However, it is the absence of gravity that causes the most problems, making flames roughly assume the shape of the burning object, rather than rising straight up as they would on Earth.

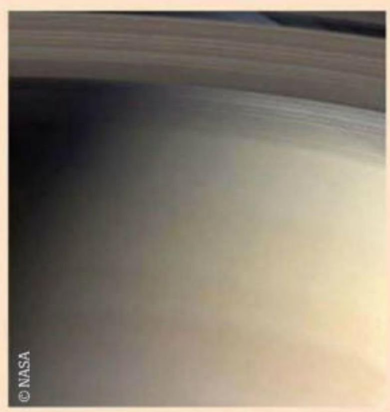
Detection is another problem as, without gravity, smoke will not rise, meaning smoke detectors must be located in the ventilation system. Once a fire is found, the actual extinguishing would be down to astronauts using either water-based foam extinguishers or compressed CO_2 units. In January 2012, the second phase of the Flame Extinguishment Experiment (FLEX) began. FLEX is designed to explore how flames react and how fuel moves in space – particularly in the Destiny Module where the ISS's fuel and ignition systems are located. A sealed chamber is being used to simulate different atmospheric conditions, using a Multi-user Droplet Combustion Apparatus (MDCA). The flames will then be analysed at NASA's Glenn Research Center in Ohio, USA.
Mike Anderiesz

What would Saturn's rings look like from the surface of the planet?

Mick Turner

Since Saturn is a gaseous planet, it's not possible to send any sort of spacecraft to the surface. However, several probes have performed flybys – the first being NASA's Pioneer 11, which came within 21,000 kilometres (13,048 miles) of Saturn's cloud tops. It passed under the ring planes, and images showed a reversal of what we see from Earth through a telescope: the rings looked dark and the gaps between them looked bright. This is probably because sunlight was passing through the gaps, and not reflecting off the icy dust particles in the rings.

Further probes, including the recent Cassini, have shown us there are seven main groups of rings, but the total number is unknown. There are also moons embedded in the rings, and the particles within the rings are always moving and reforming. Information from Cassini led astronomers to speculate that some of the rings even have their own atmosphere. Add to all this the fact that the rings move, some of them are tilted, and that Saturn has its own movements going on, and you'll see why the planet's rings continue to be so mysterious… and why it's very difficult to say exactly how they'd look were you able to stand on Saturn and look up. You'd probably see both light and dark depending on where you were located and what was happening in the various orbits and gravitational forces.
Shanna Freeman



Are astronauts able to belch?

Lee Norman

Burps, or belches, are caused by a vibration of the upper oesophagus as gas is expelled through it. This could be oxygen and nitrogen after breathing in too fast, or carbon dioxide after glugging a fizzy drink or suffering a bout of indigestion. There's nothing about space that would cause this natural bodily reaction to stop, however there would be fewer things to trigger it. For instance, astronaut diets are carefully formulated for easy digestion and cola would certainly not be part of it. Even if it were, carbonated drinks don't fizz in space as there is no gravity to separate the gas from the water, leaving air bubbles simply floating in the liquid.

Mike Anderiesz

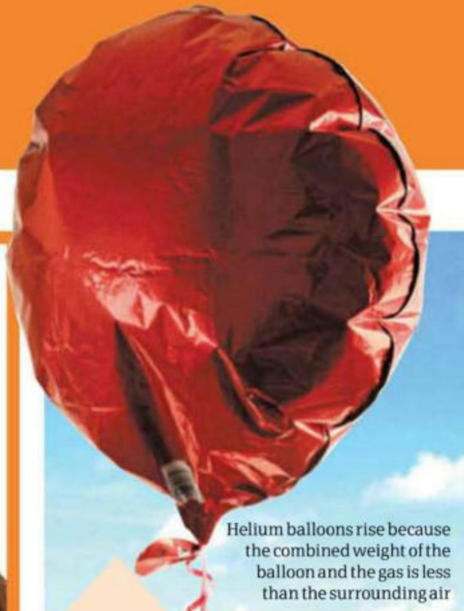
If we're constantly shedding our skin, how much do we lose over a lifetime?

Oscar Ruiz

Skin is our body's largest organ – on average an adult has about two square metres (22 square feet) of it, or in weight about 3.6 kilograms (eight pounds).

It protects our internal organs, produces vitamins and minerals, provides tactile feedback, and helps us retain water; that's why keeping it moisturised and well protected is so important. Since it's so hard-working and subject to so much, though, skin constantly needs to reproduce itself. For each minute that goes by, you've shed 40,000 skin cells, and your skin is entirely renewed every 35 or so days. So if you live for 80 years, you'll have renewed your skin approximately 800 times, shedding up to 2,880 kilograms (6,400 pounds).

Shanna Freeman



Helium balloons rise because the combined weight of the balloon and the gas is less than the surrounding air

If I let a balloon go, how high can it get before it pops, and why?

Charlene Oliver

At sea level there is about one ton of pressure exerted on you by the air at all times. This pressure comes from the 100 kilometres (60 miles) of air above weighing down the air below. As helium balloons rise, the atmospheric pressure drops as there is less air above, causing the balloon to expand. This expansion will continue until either the gas inside the balloon is of equal density to the air outside the balloon, or it pops due to the latex not being able to stretch any more (the latter being the most likely scenario).

Rik Sargent

What's the difference between a dolphin and a porpoise?

Mira Coxhill

Of the two marine mammals, porpoises are shorter and fatter (indeed, the name comes from the Latin porcopiscus, which means pig-fish) and have a blunt jaw, rather than the beak of a dolphin. Dolphins also have a bulge at the top of the head, just in front of the blowhole, called the melon. This is filled with fat and acts as an acoustic chamber for echolocation. Porpoises have an echolocation sense too but no melon, and are generally less acrobatic and playful than dolphins. They are both members of the toothed whales (odontoceti) and evolved into different families about 15 million years ago.

Luis Villazon

Dolphins can grow up to 3-4.2m (10-14ft) compared to porpoises which are shorter at 1.5-2m (5-6.6ft)

Why does running water make us want to pee? Find out on page 87

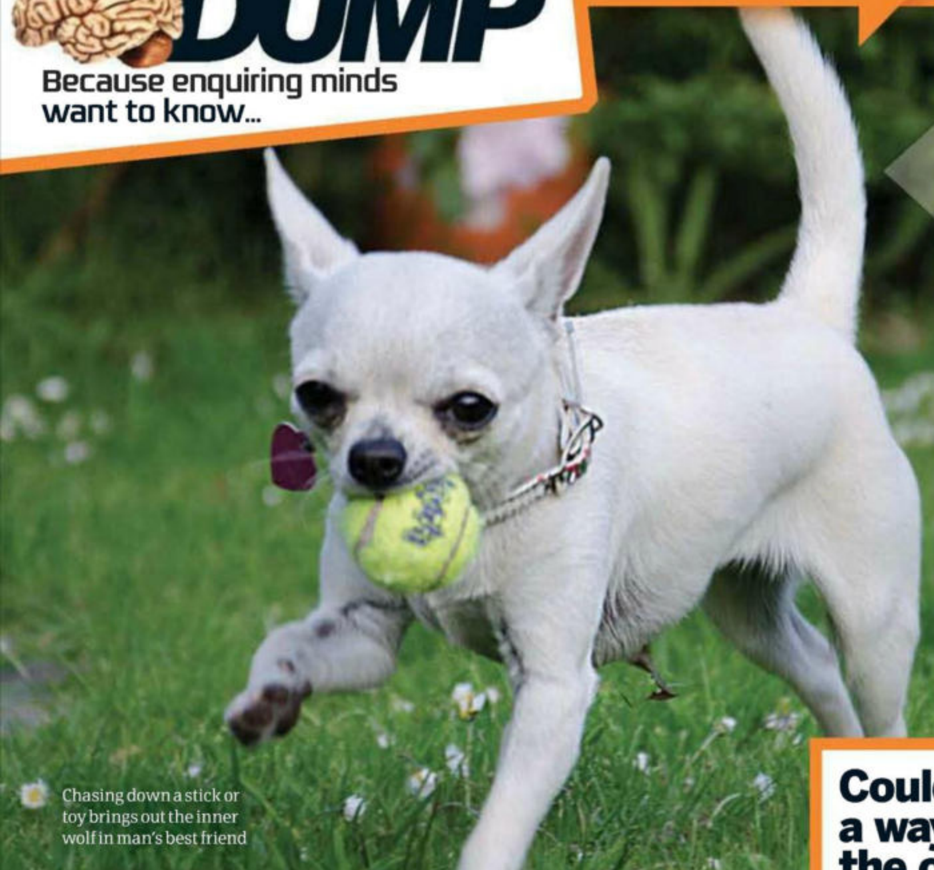
BRAIN DUMP

Because enquiring minds want to know...

How do maggots get into food?
Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered



Chasing down a stick or toy brings out the inner wolf in man's best friend

Why do dogs like chasing things you have thrown?

Stefan Rogers-Coltman, aged 13

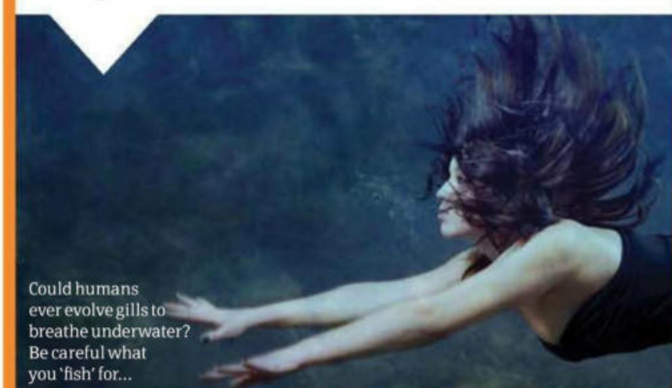
Dog are descended from wolves that chased after mammals and birds for food, so the chase instinct is already present from birth. But domestication has also created a link between dogs and humans. Dogs actively seek play opportunities with us because they want our approval. Consider the question from the other perspective: why do we like throwing things for dogs to chase? We like it because the dog enjoys it and we find its happiness rewarding. Dog and owner are engaged in a mutual back-scratching exercise, where the pleasure of one reinforces the pleasure of the other in a cycle.
Luis Villazon

Could scientists ever develop a way for humans to extract the oxygen from water?

Cameron Whitaker

Oxygen can be extracted from water in a process known as electrolysis. Water molecules consist of two hydrogen atoms paired with one oxygen atom. Connecting two electrodes to a power supply and placing them into salted water allows an electric current to flow. Electricity is the flow of electrons, therefore one of the electrodes – the cathode – becomes negatively charged due to the buildup of electrons, while the other – the anode – becomes positively charged because of an electron deficit. This difference in charge causes water molecules to separate into their constituent parts, with oxygen bubbles appearing on the anode and hydrogen bubbles accumulating on the cathode.

Your question could also be referring to whether we might one day be able to 'breathe' in the water. To do this, humans would need a system similar to fish gills in order to harness dissolved oxygen. All water in contact with the air will contain a small amount of dissolved oxygen – around five millilitres (0.01 pints) per litre (2.1 pints) – and it is this oxygen that diffuses into the bloodstream flowing through gills. It's impossible to know if humans could ever 'evolve' gills, however it is unlikely to serve any practical use since there is plenty of oxygen in the air.
Rik Sargent



Could humans ever evolve gills to breathe underwater? Be careful what you 'fish' for...

I'm often delayed by signal failures – what exactly does this mean?

James Francis

Signal failures are almost as old as the railway itself – with the first primitive wayside signalling systems being introduced in 1832. These days signalling relies on a combination of movable sections of track (known as points), track circuits that detect the position of the train and the signals themselves, which look like traffic lights positioned above or beside the track. These three elements must be routed via cables to a signalling centre where each signal change must be co-ordinated. With such a complex system, the reasons for a signal failure could be anything from power outages and circuit failures to track points freezing or the increasingly widespread problem of stolen cables and vandalism. Identifying the cause of the problem often takes longer than fixing it.
Mike Anderiesz

Why do the upper arm and upper leg have only one bone, while the lower arm and lower leg have two bones?

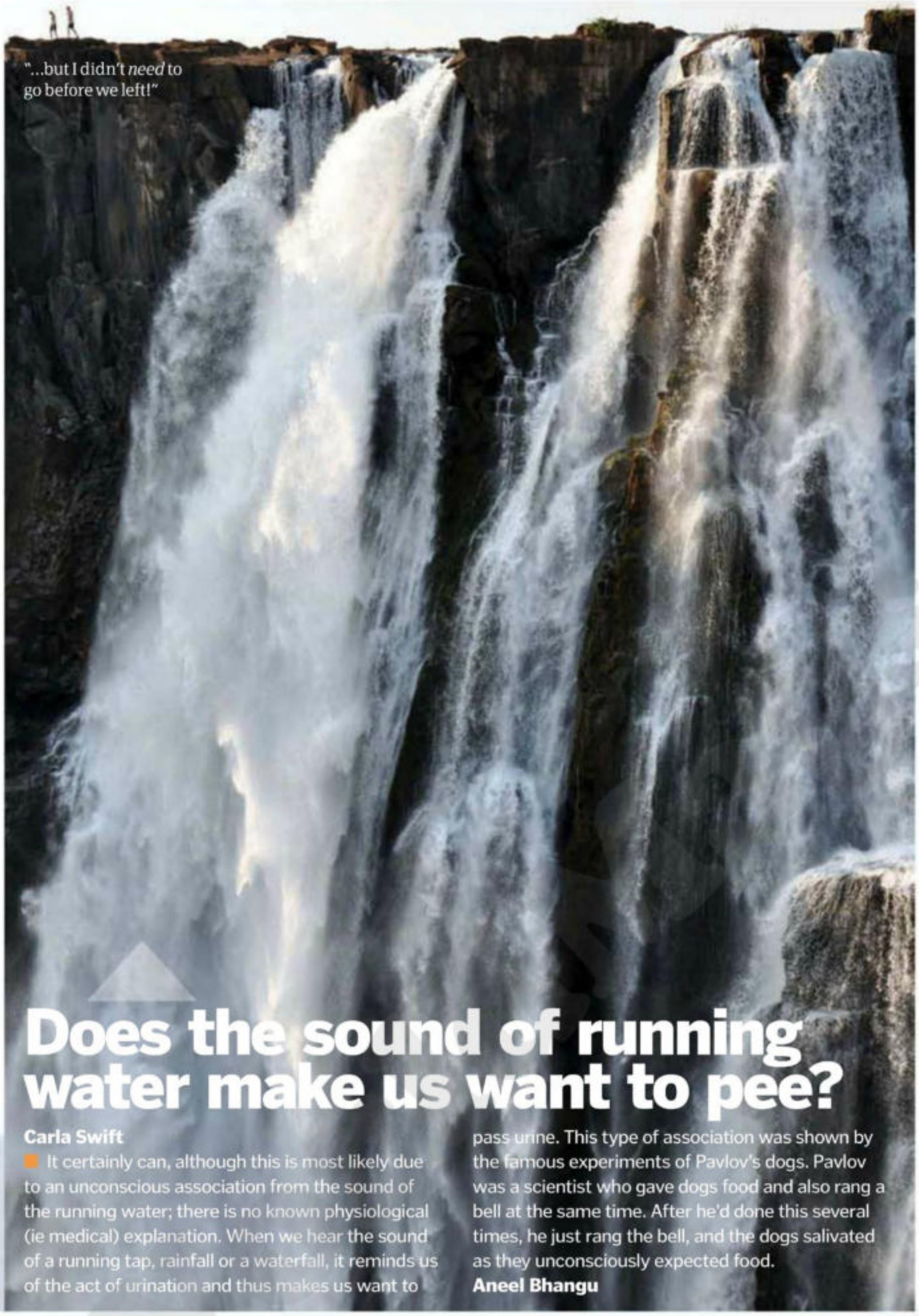
Purple ranger

The makeup of the human skeleton is a fantastic display of evolution that has left us with the ability to perform incredibly complex tasks without even thinking about them. There are several different types of joint between bones in your body, which reflect their function; some are strong and allow little movement, while others are weak but allow free movement. The forearm and lower leg have two bones, which form plane joints at the wrist and ankle. This type of joint allows for a range of fine movements, including gliding and rotation. The hinge joints at your elbows and knees allow for less lateral (sideways) movement, but they are very strong. The shoulders and hips, meanwhile, are ball-and-socket joints, which allow for a wide, if not overly refined, range of motion.
Aneel Bhangu

Where do maggots come from when food goes bad?

Dave Kitchener

For hundreds of years, many scientists used the example of maggots 'magically' appearing in rotting meat as proof of spontaneous generation – the ability for life to form in a 'dead' object. But in reality, maggots are immature fly larvae. They hatch from eggs laid by flies, but the eggs are so tiny that they are invisible to the naked eye. Decomposing food is the perfect meal for maggots, so flies are great at finding that old piece of fruit on your counter. Get rid of rotting food, keep your bin sealed, and you won't give flies a place to lay their eggs.
Shanna Freeman



"...but I didn't *need* to go before we left!"

Does the sound of running water make us want to pee?

Carla Swift

It certainly can, although this is most likely due to an unconscious association from the sound of the running water; there is no known physiological (ie medical) explanation. When we hear the sound of a running tap, rainfall or a waterfall, it reminds us of the act of urination and thus makes us want to pass urine. This type of association was shown by the famous experiments of Pavlov's dogs. Pavlov was a scientist who gave dogs food and also rang a bell at the same time. After he'd done this several times, he just rang the bell, and the dogs salivated as they unconsciously expected food.
Aneel Bhangu

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

Cyborg R.A.T. 9 Gaming Mouse

Price: £119.99/$149.99

Get it from: www.cyborggaming.com

We've seen high-end gaming peripherals in all shapes and sizes before, but the Cyborg R.A.T. 9 is possibly the most left-field mouse we've played with. It's what we'd imagine a very small Transformer could look like when in disguise. It has a crazy configuration of knobs, buttons and twiddly bits, which makes for a slightly intimidating first encounter, even for a seasoned PC gamer. But actually, it's all very practical. It's part of the R.A.T. custom configuration, so depending on your grip, this wireless mouse can be adjusted for a more comfortable fit and weight. It's fleshed out with six programmable buttons, four dpi settings, up to 6,400 dpi for the most twitchy games, and a spare rechargeable battery, for whenever the nine-hour life on your current cell dries up. As far as wireless gaming mice are concerned, it's quite reasonably priced too and, given the robust build (it has an aluminium chassis), serious gamers should be left feeling they've got bang for their buck.

HOW IT WORKS

GOOGLE EARTH

Google Earth uses satellites with telescopic cameras to take tons of photographs, then stitches them all together into polygonal tiles.

HOW IT WORKS

SILICONE RUBBER

The Grippy Pad is made of an advanced silicone that acts in a similar way to gecko feet. A more advanced version being developed by US polymer researchers can stick 317kg (700lb) to 40cm² (16in²).

HOW IT WORKS

CAPACITIVE PENS

Touchscreen pens, which work on devices like the iPad, use the natural electrical capacitance of your hand and transfer it using conductive fibres through to the nib.

Britain From Above: Month By Month

Price: £20/$44.50

Get it from: www.dk.com

From his base in London, photographer Jason Hawkes has taken helicopter rides all over the UK, snapping photos along the way. The result is a mesmerising compilation of aerial images, sorted into the seasons in which they were shot. Alongside brief insights into his inspiration and the nature of each composition are photos of both natural and industrial scenes, from Loch Ness to Caerphilly Castle. It's a fascinating book, whether as a source of inspiration or if you simply must know what the M25 looks like from above.

HOW IT WORKS

WIRELESS MICE

The R.A.T. 9 uses radio frequencies to transmit clicks and movements to a receiver that plugs into the PC. It transmits at 2.4GHz, offering just a one-millisecond delay.

Ruark R4i Integrated Music System

Price: £549.95/$N/A
Get it from: www.ruarkaudio.com

Given the choice, we'd pick a retro walnut finish for a music system over black or white lacquer every time. Perhaps it's because Ruark is rewarding good taste then, by making this walnut version of its R4i music system £50 cheaper than the other optional finishes? You won't find us complaining. In fact, there isn't a lot to complain about with the R4i in general – in terms of sound quality and features anyway. It's the kind of audio device you'd find in the bedroom of a stylish modern flat. It's host to all the usual technologies plus DAB and DAB+ compatibility, a multi-format CD player, universal iPod dock, additional speaker ports and an 80W RMS 2.1 speaker system. That's ample acoustic welly for your typical bedroom and a very rich sound at that, even if the price leaves us smarting.

HOW IT WORKS
DAB STANDARD
DAB and its successor DAB+ are transmission standards that use compression techniques and multiplexing (the combination of several signals) to reduce noise and allow features like autotuning as well as real-time text display.

Grippy Pad

Price: £6.99/$11
Get it from: www.firebox.com

Remember that gooey stuff in a pot you could buy from a joke shop? Grippy is a bit like that, but much more solid and a lot less nasty. It's an adhesive pad designed to stick to anything and adhere almost anything to it and, because it leaves no trace, can be used on anything. In practice some everyday items we tried – a watch and a pair of glasses – didn't stick as well as a spoon and pen, but it did also hold an iPhone in place quite easily. We're not sure what problem this solves for us personally, but for the low price, someone will definitely be able to make use of it.

Bamboo Stylus Duo

Price: £34.99/$39.95
Get it from: http://bamboostylus.wacom.eu

It's a ballpoint pen, but flip it over and it's also a stylus. The rubberised nib of the Bamboo Stylus Duo is slimmer than your typical stylus for more accurate scribbles, whether you're taking notes in Bamboo's free iPad app (Bamboo Paper) or touching up a technical drawing. It's a steep price if all you're doing is messing about in Draw Something, especially as a finger will suffice, but nevertheless the Duo makes for an extremely comfortable and accurate stylus.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

EDITOR'S CHOICE AWARD

iPad: Brian Cox's Wonders of the Universe

Price: £4.99/$6.99
Developer: HarperCollins Publishers Limited
Version: 1.1.1 **Size:** 343MB **Rated:** 4+

This dedicated app to the BBC series places the wonders of the universe at your fingertips. There are video clips, image galleries and masses of text to scroll through. The manner in which it's presented is the most impressive feature of this app, however, with an interactive cosmos that you can pinch-zoom and swipe across to find different topics (choosing between over 200 articles and two-plus hours of video). This is what all educational apps should be like: head-turning visuals and loads of content to inspire and inform.

Verdict: ●●●●●

iPhone: Snapguide

Price: Free
Developer: Heavy Bits
Version: 1.0.2 **Size:** 12.6MB
Rated: 4+

Snapguide is a beautifully designed app that allows you to view hundreds of different how-to guides on varying subjects, and create your own. Each guide follows a step-by-step process that is easily navigated. Steps can include videos, photos or just text depending on the task's complexity.

Verdict: ●●●●●

Fitness monitors

Helping you boost performance, lose weight and improve your lifestyle

Garmin Forerunner 110

Price: £169.99/$229.99

Get it from: www.garmin.com

Many of us wear a watch and runners and cyclists generally like to know their times over a certain distance. It's the reason that, since the dawn of the digital LCD watch in the Seventies, new wristwatches often incorporate stopwatch and timer functions in addition to a simple clock. So Garmin has taken that concept a few steps further...

For most of your day the Forerunner 110 is a simple digital watch, but below the proverbial tip of this iceberg is a suite of fitness-tracking features that can be a real boon to your performance. To begin with, it incorporates GPS to precisely measure the distance you've run while wirelessly linking to a pair of electrodes strapped just below your chest to monitor your heart rate. Once you've completed your routine, you can plug the Forerunner 110 into your PC via a bespoke USB cable, log in to the Garmin website, then upload the data gathered to track your distance, times and calories burned. Of these three devices tested here, the Forerunner 110 is best suited to those runners and cyclists who know how to get what they want out of their routine.

Verdict:

Fitbit Ultra

Price: £79.99/$99.95

Get it from: www.fitbit.com

At the other end of this spectrum of fitness monitors – and with a price tag to reflect its more basic functionality – it's the Fitbit Ultra. This is a very compact, USB drive-sized device that simply clips onto a pocket or straps around your wrist where, once synced with a Fitbit account online, it can go to work taking various measurements. Like the Ki Fit, it will tell you how long you've slept for, the calories you've burned over the course of the day, how active you've been and, of course, the mandatory pedometer – which in itself isn't such an accurate way of gauging activity but, combined with the other measurements, can give a runner an idea of what they need to work on. The Fitbit will also give you a breakdown of where you could try to improve, based on targets you've set yourself – albeit on a more basic level. It's less accurate and not as fully featured as the Ki Fit package, but it has two advantages: it's cheaper and you don't need a subscription. Casual runners will benefit from it the most, but more dedicated sportsfolk might want to look for a solution that will better suit their needs.

Verdict:

Ki Fit Armband Audit Package

Price: £176.99/$N/A

Get it from: www.kiperformance.co.uk

The Ki Fit is a comprehensive device that combines a handful of funky sensors into a watch-sized box that straps onto your arm. It has a standard pedometer, a motion detector plus a trio of sensors that measure heat flux, skin temperature and something called galvanic skin response (essentially, sweat). It's designed, ideally, to be worn all the time: when you exercise, while at work and even while sleeping. To get the best out of it, the only time it should be taken off is to clean, recharge and upload to your profile on the Ki Fit website. In return it gives you accurate readings on calories burned, the time you've exercised, the amount of quality sleep you've had and more. The website will monitor nutritional data too, so the Ki Fit is compatible with almost anyone's routine, from fitness fanatics to those who just want to shed a few pounds. You do need a subscription, however, which bumps up the cost considerably, but used properly it can prove an invaluable aid to a better lifestyle.

Verdict:

HOW IT WORKS SUBSCRIPTION

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NEXT ISSUE
Drive a tank
Build a fire from scratch

JUGGLE

Juggling three balls can be learnt quickly, just follow these five simple instructions

1 Ball 1
To start, take two balls in your right hand and one in your left. Then, throw one of the right-hand balls to the left hand so that it proceeds in an arc, the apex of which should be at eye level.

2 Ball 2
Then, as this first ball reaches the apex of its arc (ie when it is in front of your eyes), throw the ball in your left hand in a similar arc towards your right hand. With your left hand now free, catch the first ball as it descends.

3 Ball 3
Finally, as the second ball you threw from your left hand reaches the peak of its arc, throw the remaining third ball in another arc from your right hand. With your right hand now free, you can catch the incoming second ball.

4 Repeat
At this stage, it is advisable to simply catch the remaining airborne ball (ball 3) in your left hand and stop. If all's gone to plan, you should now have two balls in your left hand and one in your right. Once you have confidently tackled the previous three steps, now try to continue the juggle, which is achieved by throwing ball 1 out of your left hand as ball 3 hits the apex of its arc.

5 Corrections
There are two main issues that amateurs encounter when learning to juggle. Firstly, they unconsciously move forwards as they juggle, leading to an eventual collapse in the ball loop. To counter this, try juggling in front of a wall or bed. Secondly, they run out of time to catch any ball. This is caused by uneven ball arcs, so to rectify this problem, try to keep each ball throw at a uniform height (ie so each ball hits its arc apex in front of your eyes).

CHANGE A FLAT TYRE

Broken down at the wayside with a punctured tyre? Follow these instructions to get back on the road

1. SAFETY FIRST

Before you do anything, ensure that your car is on a flat, stable surface and as far away from passing traffic as possible. In addition, put on your hazard warning lights and apply the handbrake.

2. BRACE

Next, if possible, place a couple of heavy objects in front of the rear and front wheels on the side with the puncture. Extra tyres, rocks and weights all work well. This is simply to add an extra level of stability to the car.

3. RETRIEVAL

Now it is time to remove the spare tyre and jack from the car. These are normally positioned in the boot (trunk), located under the floor panel. The floor panel can be lifted by a pair of tabs found near the rear base of the boot (ie the end closest to you).

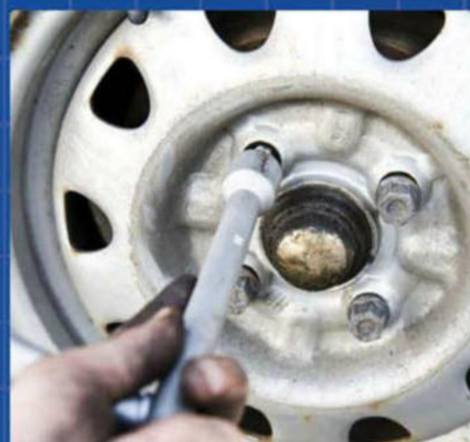
4. JACK

Jacking the car is easy, provided you position the jack in the correct place. Ideally you want the jack to make contact with the metal frame of the vehicle as close as possible to the punctured tyre. Most cars come equipped with jacking points either to the fore or rear of each tyre. Under no circumstances jack the car from the trim.

The secret to tyre-changing success is preparation, patience and keeping the key equipment close to hand

5. SUPPORT

Now raise the jack until it is just supporting the weight of the car. You do not want to raise the car entirely off the ground straight away as now we need to check if the jack is securely positioned – if it isn't, lower the car and reposition the jack so it's perpendicular.



6. LOOSEN

With the jack just taking the weight of the vehicle, take a wrench (these are also typically equipped to most cars under the boot flooring) and loosen the wheel nuts. Do not completely remove these nuts, however.

7. RAISE

Now, with the nuts loosened and the jack level, lift the car off the ground so there is enough room to remove the flat tyre. This is achieved by completely removing each of the wheel nuts, by turning them clockwise with the wrench.

8. REPLACE

Now slot the replacement tyre onto the car wheel hub, ensuring that it is correctly aligned. Once this is done, replace the nuts and tighten them – when doing this, try to tighten all at the same rate, doing a little on each repeatedly until fixed, rather than turning one to full tightness and then the next.

9. LOWER

Now lower the car on the jack until the tyre is just touching the ground and tighten the nuts again to ensure the tyre is not loose.

10. GOOD TO GO

Finally, lower the car to the ground fully and remove the jack. Tighten the nuts once more for peace of mind and place the old tyre, jack and wrench back into the boot. You have now changed your flat tyre and are ready to get on with your journey!

HARD BOIL AN EGG

Follow these five steps and get 'eggs-ellent' results every time

1 Gentle

Start with your selection of eggs in a pan of cold water, with all the eggs on the same layer (ie do not pile eggs on top of each other) and five centimetres (two inches) of water covering them. Then bring the pan of water to the boil slowly, while adding a pinch or two of salt. Both these techniques will prevent the eggs from cracking while cooking.

2 Simmer

As soon as the water begins to boil remove the pan from the hob and drop the heat to a lower setting. Then replace the pan and leave the eggs to simmer for precisely one minute.

3 Cover

After the minute has passed, once again remove the pan from the heat, cover it, and then let it sit for ten minutes. Next remove one of the eggs with a slotted spoon, run some cold tap water over it and cut it in half. If the egg isn't quite done, wait an additional couple of minutes before removing the remaining eggs from the pan.

4 Ice

As you remove each egg deposit it into a bowl of ice water. Once the eggs have cooled strain the water out of the pan and then dry them off. If the eggs are to be eaten immediately, they can now be peeled; if not, place them within a sealed container and put in a fridge.

5 Cracking

The best way to peel hard-boiled eggs is to crack the shell on all sides on a hard surface and then roll the entire egg between your hands in a repetitive motion. The rolling motion will gradually loosen more and more of the shell without splitting the egg within.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 How heavy is the Krupp Bagger 288?
A:

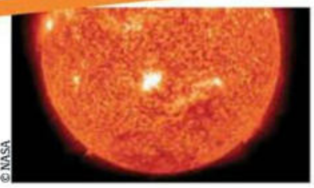
2 What is the average daily traffic that crosses the Golden Gate Bridge?
A:

3 At what temperature should you cook short pastry?
A:

4 How long is the runway at Ford's crash test centre in Merkenich, Germany?
A:

© NASA

5 What are the technicians who work on rocket launch pads sometimes called?
A:



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6 How hot is the Sun's core in degrees Celsius?
A:

7 How many points were awarded for a helmet strike in the sport of jousting?
A:

8 What is considered the home of cuckoo clock manufacture?
A:

9 How many species of triceratops are officially validated?
A:

10 What is the total height of the Hammetschwand Lift in Lucerne, Switzerland?
A:

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> ISSUE 34 ANSWERS

1. 13,000mph **2.** 1904 **3.** 1.1kg **4.** 1995 **5.** 120mm **6.** 20% **7.** 42 **8.** 13m **9.** Khafre **10.** 37°C

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FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Could Raspberry Pi inspire a new generation to get hands on with computers?

Letter of the Month

Rose-tinted Raspberry

I recently picked up the March issue (32) of **How It Works** at my local Costco. The article on the Raspberry Pi computer brought back fond memories.

Back in the late-Seventies I had a single-board computer called the Netronics ELF II (as I recall it cost about the same as the Raspberry Pi, or perhaps a little more). This machine had a 1.79MHz 8-bit processor with 256 bytes of RAM. The maximum video resolution was 64 x 128 monochrome (though I came up with a hardware modification to get it to 128 x 128). Data storage was by cassette tape, which wasn't even standard – you had to buy an additional board, which was also required to hook up a keyboard; there was no provision for a mouse, though I imagine I could have come up with something if I had thought of it. How far we have come in 30 years!

My hardware tinkering days are long past, though I still do some programming in BASIC. Over the years I dabbled in C, Pascal and even assembly language and, of course, worked with machine language on the ELF, but it is nice to see that young people today have the opportunity to have the kind of experience I had in a modern context.

Michael A Zachary, Phoenix, AZ, USA

HIW: Indeed, things have changed since the days when the bedroom programmer and hardware boffin could take the market by storm, but the access amateur computer enthusiasts have to tech today is inspiring. The Raspberry Pi in particular encapsulates the entrepreneurial spirit of computing for everyone. It's incredible that in 30 years, that hobbyist ELF II has inspired a 700MHz, 256MB RAM computer that fits into something the size of a credit card! Talking of modern technology, enjoy your prize, Michael!

Win! A WOWee One portable speaker

A matter of light

When Albert Einstein wrote $E=mc^2$ he knew that the speed of light (c) could not be exceeded. So why did he use c squared? And, if c squared is impossible, does the formula still work?

Harry Bingham

HIW: The most famous equation in the world states the relationship between energy (E) and mass (m) and that there's a constant correlation between the two. Einstein said that 'mass and energy are both but different manifestations of the same thing'. His theory of relativity states that all observers are governed by the same physical laws regardless of how fast they are moving, and this equation shows the speed of light (the maximum possible speed) squared is the conversion factor between mass and energy. It reveals the huge potential energy that any unit of mass has and why nuclear fission (in the form of a bomb or power station) can yield enormous amounts of energy from relatively tiny quantities of matter.

A touch of glass

Hi! Do all types of glass block all types of infrared light? Is glass made of a certain composition better at blocking infrared?

Lucy

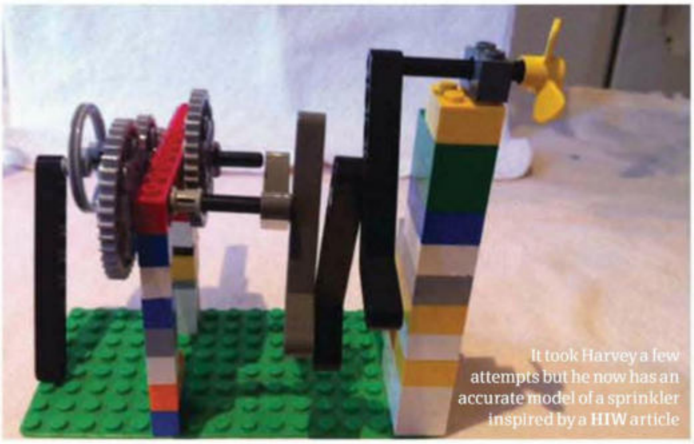
HIW: The infrared spectrum extends from 0.74-1,000 micrometres (that's one millimetre), immediately following the visible part of the spectrum. Modern glass is designed to allow us to see through it yet keep heat in, so shorter, visible wavelengths pass through while longer-wave infrared heat energy is reflected. Not all glass has this property though: lenses for thermal imaging cameras can be made out of coated germanium or sapphire that allow IR wavelengths to pass.

Superman

I was doing the sci-fi flowchart in issue 32 when I saw the question about the flux capacitor and thought of something impossible: if we could possibly reverse the direction of the Earth's rotation or our direction of orbit around the Sun, would it reverse time?

Oisin Goddard (10)

HIW: It's an interesting idea, Oisin, but we're not convinced it would work in practice. Unlike the scene in *Superman*, reversing the rotation of the Earth will most likely cause catastrophic earthquakes and geological disasters for all life on our planet as magnetic fields and magma tides beneath the crust shift significantly. In addition, let's not forget the kind of event it would take to make this happen – one theory suggests that the last time the rotation of the Earth reversed was billions of years ago, when a planet



It took Harvey a few attempts but he now has an accurate model of a sprinkler inspired by a HIW article

the size of Mars collided with Earth, which went on to form the moon.

Cam-can

Hi, I made a cam out of LEGO using the sprinkler article in issue 11. I saw the diagram and decided to make a LEGO model, got all the pieces then made v1… A few tests later it worked perfectly.

Harvey Aitken (12)

HIW: Great work, Harvey, and thanks for the photo. We think you've got the basic principle of the oscillating sprinkler mechanism spot-on. All you need to do now is replace the lever-driven motion with a turbine and you'll have a working sprinkler! Best set that one up in the garden though – or things could get a bit wet!

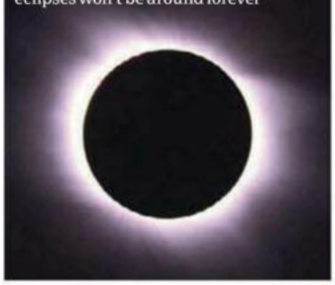
Moonlighting

I've never seen a solar eclipse, but from the images I've seen it looks like the moon is exactly the right size to cover the Sun. If the moon were smaller it wouldn't cover all the Sun and we would see the star like a ring doughnut (with the moon hiding just the centre). If the moon were bigger we wouldn't see the Sun's halo during the eclipse (ie the moon would block the halo out). Is there a mathematical reason why the moon and the Sun are just the right size and distance from the Earth to create the perfect eclipse?

Andrew Weighill

HIW: Thanks for writing in with your query, Andrew – there's no doubt there's something very captivating about eclipses. The short answer is that it's most likely a complete coincidence, 'most likely' because we only know of around 700 planets and little of their moons. We do know that the diameter of the Sun is 400 times that of the moon, but the moon is 400 times closer to Earth, so they appear around the same size. Because the moon travels in an elliptical orbit though, its size in the sky does vary, so sometimes we get total solar eclipses and other times we get partial (or annular) eclipses. Additionally, the moon is constantly moving away from the Earth at a rate of around four centimetres (1.6 inches) a year, so eventually we'll have no more total solar eclipses.

As the moon continually moves away from our planet total solar eclipses won't be around forever



What's happening on… Twitter?

We love to hear from **How It Works'** dedicated readers and followers, with all of your queries and comments about the magazine. Here we pull together a varied selection of the most interesting tweets from the last month.

Miss_Mitchell
@HowItWorksmag
@HowItWorksmag arrived today. Airpunch!

Money4Machines
@HowItWorksmag
At first glance we read 'titanic badger' – the stuff of dreams!

mst3kuk
@HowItWorksmag
Did you know… Concorde used to fly at [18,300m] 60,000ft where the air outside is only [0.07kg/cm^2] 1psi, on the edge of space!

StarryEyedTruth
@HowItWorksmag
What are those atoms or particles that are bonded and even when separated by distance they still mirror each other?

bittenapple
@HowItWorksmag
A simple question: what is the shape of the universe?

Owieh
@HowItWorksmag
That definitely looks like a spider's head. Or it could be a mutant owl-spider hybrid…

Sparkcafe
@HowItWorksmag
Congrats on a brilliant mag. Finally, something that gets my 13yr old son reading :) when he can get it from me that is!

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JOURNEY TO THE RED PLANET

In August this year, the Mars Science Laboratory is due to touch down on Mars. Its mission is to investigate the planet's previous or present ability to sustain microbial life. Find out how the mobile lab reached the planet, how it will land and what it will do there next issue…

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ANSWERED NEXT ISSUE

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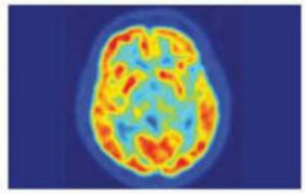
How can we overcome a phobia?



Is it possible to see your thoughts take shape?

What engineering powers a bulldozer?

How does a spider spin its complex web?

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